The STRAUSS BASCULE BRIDGE COMPANY

Bascule and Direct Lift Bridges

· CHICAGO · U · S · A ·

THE STRAUSS BASCULE BRIDGE COMPANY, Inc.

Engineers and Designers of

Trunnion, Bascule and Direct Lift Bridges

MAIN OFFICE
104 South Michigan Avenue
CHICAGO, U. S. A.

Cable Address: "BASCULE, CHICAGO"

EASTERN OFFICE
30 Church Street
NEW YORK, N. Y.

CANADIAN OFFICE
14 Windsor Hotel
MONTREAL, QUE.

GREAT NORTHERN RY. BRIDGE, SEATTLE, WASHINGTON
View graphically showing comparative height long, single leaf STRAUSS Heel Trunnion Bridge (open) and twenty-story office building

IN Strauss Bridges we have sought, and in the main have realized, the accomplishment of that ideal combination of first quality and lowest cost, which the world has a right to expect from the engineer and which, in large degree, is the measure of its progress.

Index

Foreword

THE STRAUSS BASCULE BRIDGE COMPANY herewith presents a brief description of its various types of bascule and lift bridges, developed in fourteen years' practice in the design of such structures, as well as the advantages of these types in respect to economy, efficiency and range of adaptability under varying conditions.

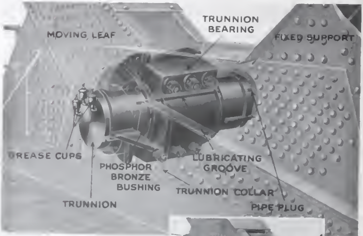
All STRAUSS bridges are characterized by the use of trunnions upon which the parts of the bridge move. The superiority of the trunnion as a mechanical device is now generally conceded for movable bridges. No less important is the Strauss parallel motion system controlling the movement of the counterweight, which is in part accountable for the exceptional adaptability of the design.

Strauss Bridges are designed by the Strauss Bascule Bridge Co., an Illinois corporation organized in 1904. The Company maintains a staff of engineers of wide experience in movable bridge design and construction, headed by its founder, J. B. Strauss, C. E., who is actively engaged in the conduct of the Company as President and Chief Engineer. The progressive development of the Company is evidenced by its 15 United States patents and an equal number of foreign patents issued to Mr. Strauss from time to time and a series of applications, issue of which is pending. All these patents have been consecutively applied in practice.

STRAUSS bridges in use and under construction, range in length of span from 31 feet to 336 feet and comprise structures purely utilitarian in character as well as those which are architecturally attractive. Governments, States, Municipalities, Counties, Railway Companies, and Private Corporations all have found it economical and efficient to make use of our experience and facilities for the design of movable bridges.

The Trunnion—The Keystone of Bascule Efficiency

The Strauss Bascule Bridge may truly be considered as built around the "trunnion." The trunnion is a short shaft upon which the leaf, so called, i. e., the movable section of the bridge, is mounted, and about which it rotates. It is the "element of movement," the vital element of every bascule, upon which the efficiency of the entire structure depends.



Phantom View

Self-evidently, the element of movement of a bascule bridge must be of unquestionable integrity. This is true of the trunnion because the stresses to which it is subjected can be definitely determined and provided for. The trunnion carries its load in surface bearing. It is only necessary, therefore, to fix a safe pressure per square inch in order to determine the extent of surface, i. e., the size of the trunnion required, which at once guarantees that it will carry the load imposed upon it *without overstress*. In

Actual View

other words, the trunnion can be designed as accurately, and with the same factor of safety, as any portion of the bridge proper; *it is never overloaded, no matter how large or heavy the bridge.*

The next important characteristic of the trunnion is its adaptability to complete protection and lubrication. This is clearly illustrated in the "phantom view" shown herewith, representing the 17-inch heel trunnion of the 3-track, 186-foot span of the Chicago & Northwestern Ry. Co., at Deering, Chicago. It will be noted that the entire element of movement (i. e., the trunnion and bearing), for this heavy structure is completely enclosed and contained within the truss chord, thus being protected from damage, rust and debris. This illustration also shows the method of securing the trunnion in its bearing, the bronze bushings, the means for access and inspection, and the connection and relation of the associated parts.

The trunnion surface is provided with three straight grooves, extending from edge to edge of the bearing, with screw compression grease cups at one end and removable pipe plugs at the other. These constitute a simple and effective lubricating system. Straight grooves are used in preference to spiral grooves, to facilitate removal of old grease at occasional intervals. The screw compression grease cups effectively distribute the lubricant over the trunnion surface, large or small. In some of our heaviest bridges, we have supplemented the grease cups by a type of "grease gun" developed by us for the purpose, whereby the lubricant may be forcibly driven through the grooves at intervals. In some cases we have installed, as a convenience, automatic pressure systems whereby lubrication is applied to all trunnions of the bridge simultaneously, from a central control. The lubricants used are ordinary commercial standards.

These trunnion details, which obtain as well for the counterweight connections, embody the results of long experience in developing the maximum efficiency of the elements of movement. They compel all movement to take place under the best possible conditions, namely on properly prepared surfaces, thoroughly clean, carefully protected and fully lubricated, and the unit pressures on which are rigidly maintained within safe low limits. And it is the fact, that these conditions can be realized and maintained in a trunnion bearing alone, that makes the trunnion the most dependable of all known methods of providing rotary movement in bascule bridges and that enables it to impart to these great machines the highest mechanical efficiency.

FIGURE 1. WHEELING & LAKE ERIE R. R. SINGLE TRACK BRIDGE OVER CUYAHOGA RIVER, CLEVELAND, OHIO
Length of Span [illegible] feet. Completed [illegible]. First Strauss Bascule Built

The First Strauss Bascule Bridge

THE illustration on the preceding page (Fig. 1) is a view of the first Strauss Bascule Bridge, erected in 1904, for the Wheeling & Lake Erie Railroad, at Cleveland, Ohio. It is a 150-foot single-leaf, single-track span, and represents the first marked advance in bascule bridge construction. Of its advantages the principal one was economy, due partly to the first application of concrete as a counterweight for bascule bridges. Up to that date, counter-weighting had been effected with cast iron or more expensive materials. The substitution of concrete involved novel means of supporting same, but the cost of concrete being (weight for weight) much less than that of cast iron, the resultant effect was a material reduction in cost, and it is a matter of record that in this first bridge a saving of Twenty-five Thousand Dollars in construction cost was realized.

The concrete counterweight of this first Strauss bridge is carried above the trusses and is pivoted thereto, being guided by the now well-known parallel-link mechanism, which is typical of all Strauss types of lift bridges, and which is described in detail in the succeeding pages. It is these and other factors found in the Wheeling & Lake Erie bridge, that are responsible for the tremendous impetus given to bascule bridge construction and for the advancement of the practical limits of size and weight of operative structures over what was considered possible in 1904.

The various designs illustrated in this catalogue are modifications of the Wheeling & Lake Erie bridge, and embody a number of important and valuable improvements, both in design and details, which have been developed from time to time, and which have realized additional economy and efficiency.

Classification of Strauss Bridges

Generally speaking, Strauss bridges are divided into four groups, as follows:

Group I. Vertical Overhead Counterweight Type.—Best adapted for locations where there is little clearance between water level and under side of bridge for leaf lengths up to about 100 feet, and where economy is a prime consideration. Through-girder and pony truss spans are best suited for this type of construction and it has also been very successfully used for converting fixed deck-plate girder bridges into bascule spans. Applies to either single or double leaf spans.

Group II. Underneath Counterweight Type.—Best adapted for locations where there is appreciable clearance between water level and under side of bridge, or where appearance is a prime consideration. Truss and girder spans of all characters well suited for this type of construction. Applies to either single or double leaf spans.

Group III. Heel Trunnion Type.—Well adapted for locations where there is little clearance between water level and under side of bridge for leaf lengths over 100 feet. Possesses advantages which render its use applicable irrespective of this clearance. Through truss spans are best suited for this type of construction for the larger and heavier bridges and semi-through spans for the lighter and shorter bridges. Applies to either single or double leaf spans.

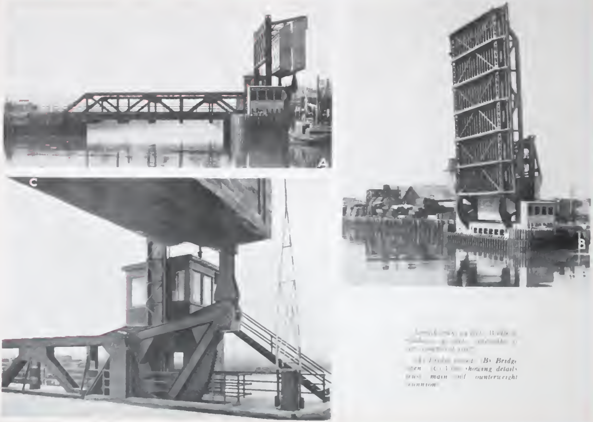
Group IV. Direct Lift Type.—Best adapted for locations where the vertical clear height between water level and under side of bridge in the open position for navigation is small in proportion to the width of navigable channel, or where the bridge is built at considerable height above water level, thereby reducing materially the vertical travel of the span. Used only for single leaf spans, of all characters, depending on length required.

Group I. Vertical Overhead Counterweight Type

FIGURE 2, (a), (b) and (c), illustrates the Vertical Overhead Counterweight Type, showing views of the Fourth Street bridge, San Francisco, completed 1917.

The main trusses are each supported by means of a trunnion (short axle), secured to the top chord, mounted in a pair of symmetrical journal-bearings, which are secured to vertical structural steel posts (termed trunnion posts) supported on and anchored to the pier. The trunnions just referred to are termed the "main trunnions" and divide the bascule span into a "long arm," spanning the navigable stream, and a "short arm," extending back toward the shore, and serve as the fulcrum about which the bascule span, or leaf, rotates a quarter turn in opening or closing.

To make up for the discrepancy in weight between the two, the short arm is weighted by means of a concrete counterweight block located in an upright position (whence the term "Vertical Overhead Counterweight" type), above the traffic clearance line of the roadway. This counterweight bears down on the extremity of the short arm of the leaf by means of supporting structural steel columns in line with the main trusses, and pivotally connected thereto by trunnions, termed "counterweight trunnions," secured to the trusses, and journal-bearings secured to the column bases. The counterweight is held in an upright position by means of a rigid member termed the "counterweight link," one end being pivoted to the top of the counterweight and the other to a fixed tower, or gallows frame, built up from the outside trunnion posts. The center line of the counterweight link is parallel and equal in length to a line joining the main and counterweight trunnions, these two points and the two link pivots forming a parallelogram by virtue of which the counterweight is constrained to move parallel with its initial position and so establishes one of the conditions that maintains the leaf in equilibrium while the bridge operates. Further details concerning conditions for equilibrium are demonstrated in the following pages.



[illegible]

(A) Bridge closed. (B) Bridge open. (C) View showing details truss, main and counterweight trunnions.

Figure 2. Single Leaf Vertical Overhead Counterweight Highway Bridge, Fourth St. over Channel St. Waterway, San Francisco, California

The span is opened and closed by two circular curved rack and pinion drives, the prime mover being electric motors. The curved racks are secured, one to each of the bottom chords of the short arm, whose centers are the main trunnions and are engaged by operating pinions keyed to shafts mounted in symmetrical journal-bearings secured to the base of the trunnion posts. These operating shafts are connected by means of transmission gears to electric motors which are controlled by the bridge tender in a suitable operator's house at the side of the bridge, supported by brackets at the end of the pier, over the sidewalk.

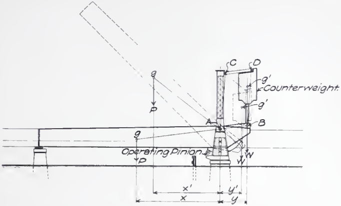


FIGURE 3. DIAGRAM VERTICAL OVERHEAD COUNTERWEIGHT TYPE

When closed the bridge is locked to the rest pier by means of a motor-driven latch bar moving in guides attached to the front end of the bridge and engaging a suitable casting anchored to the pier, the lock motor and gear train being mounted on the end of the leaf beneath the floor. The lock motor is controlled from the operator's house and is electrically interlocked with the main operating motors so that neither can be operated except in correct sequence.

Other safety measures consist of automatic cutoffs which stop the operating motors in the nearly-open and nearly-closed positions of the leaf, setting the motor brakes at the same time; in addition a mechanically-operated emergency brake is provided. Emergency hand-operation is also provided, consisting primarily of a hand crank geared to the machinery at either side of the bridge. In some instances a central hand capstan, at the center line of the roadway a short distance back of the trunnion, is employed to effect operation.

Figure 3 illustrates the conditions that maintain the leaf in equilibrium—(g) is the center of gravity of the moving leaf, whose moment is (Px), about the main trunnion (A), in which (P) is the weight of moving leaf considered concentrated at point (g). Point (g^1) is the center of

Figure 4. Single Leaf Overhead Counterweight Bridge, Illinois Central Railroad, "Lifting Truss Design" Over Big Black River, [illegible], Mississippi

[illegible] single track. Completed [illegible] before remo al

gravity of the counterweight whose moment is (Wy), about (A), in which (W) is the weight of counterweight considered concentrated at (g), and applied vertically at (B). The moment (Wy) is made equal and opposite to the moment (Px), which condition balances all vertical forces about (A), and the structure is thus in equilibrium for the closed position of the bridge. For any other position of the bridge, such as indicated in dotted lines, it can be seen that the forces are also in equilibrium by virtue of the fact that the three points, (g), (A), (B), lie in a straight line, thus establishing a constant relation between the horizontal lever arms, about (A), of leaf and counterweight, and furthermore because the counterweight is pivotally attached to the leaf and moves parallel to its initial position as explained above.

From the foregoing it will be seen that the main trunnions support the weight of leaf and counterweight, and that *this weight*, termed the "*dead load*," thus supported, is *always* a *vertical* and *constant force on the pier.*

The great advantage of the pivotal connection of the counterweight will become apparent by comparison with the use of a fixed counterweight, that is, a counterweight which is an integral part of the moving leaf. In such an arrangement, the *actual* center of gravity of the counterweight must be located on the extension of the line joining the center of gravity of the long arm and the center of rotation, i. e., at point (B) (see Fig. 3), which will necessitate the use of a cast iron or heavier metal on account of the limited space available between the bridge and water level, or else an expensive watertight pit must be built in the pier. The only other alternative, with the fixed counterweight design, is to raise the center of rotation materially, so that the counterweight may be located above the traffic clearance line, which in fact is what is resorted to at the expense of stability and economy. In the STRAUSS design, however, since the counterweight trunnion is correctly located with respect to the center of rotation and center of gravity of the long arm, the actual mass of the counterweight may be located above the clearance line without impairing the stability or the economy of the design. That is, since the effect of the counterweight is applied vertically on the counterweight trunnion in the STRAUSS design, it is immaterial where the actual center of gravity of the counterweight block is located, so long as the correct total weight is provided, which is accurately and easily obtained by casting recesses, or pockets, in the counterweight, for the purpose of adding to or taking away small concrete blocks until an exact balance is reached.

Where it is necessary to convert an existing fixed girder span into a bascule, or to build a deck-plate girder span with counterweight overhead, this type is found very satisfactory. In this form the bridge is known as the "Lifting Truss" type, illustrated in Fig. 4. The main span is not directly mounted on trunnions but is supported on the piers at each end, as if it were a fixed girder span,

and is in this case a duplicate of the series of approach spans at either side. It is counterweighted and made operative by two short bascule trusses, one outside of each main girder, and mounted on trunnion posts anchored to the pier at one end of the span and connected thereto by means of transverse beams framing to the vertical members of the lifting truss and the webs of the girders of the span.

The vertical overhead counterweight type is used for double leaf as well as for single leaf designs; there being no support at the ends of the leaves at the center of double leaf spans, means are provided to support the leaves under live load. The means usually devised for this purpose are quite similar to those employed for the underneath counterweight type described in the succeeding pages under Group II. In most cases the leaves under live load act as cantilever spans, but a notable example, where the two leaves form a three-hinged arch, is found in the highway bridge, across the harbor entrance in Copenhagen, Denmark, built by the Harbor Board in 1908, illustrated in Fig. 5. The roadway carries a double track electric railway line between the two main bascule girders. Two 10 ft. 3 in. sidewalks cantilevered from the main girders are also provided. The main girders are arched above the roadway and are provided with a compression lock at the center of the span near the top of the girders, where they meet, forming the center hinge. The end hinges are located near the bottom of the girders beneath the roadway, at the top of the piers near the channel lines. To insure proper bearing at the three hinges, the pressure of the counterweights at the tail ends of the girders is relieved by means of hydraulic cylinders when the bridge is closed.

The Copenhagen bridge also illustrates how the vertical overhead counterweight type lends itself to decorative or ornamental treatment. Fig. 6, being a portal view of the Federal Street bridge, Camden, N. J., completed in 1908, illustrates the same feature in somewhat different form. In this design the counterweight itself forms an ornamental portal over the roadway and, as the bridge operates, moves between two reinforced concrete operators' houses over the sidewalks. From the foregoing examples, it is seen that this type of bridge is capable of proper artistic treatment.

* * *

Summing up, the advantageous features of the Strauss Vertical Overhead Counterweight Type are as follows:

1. The entire dead load, leaf and counterweight, is supported directly over the center line of the pier and remains a constant vertical load during the operation of the bridge. Only one pier is required at trunnion end.

2. The points of support for the dead load, the main trunnions, are close to the pier top and positively connected to the pier by means of short steel posts anchored thereto.

3. Space for the counterweights is not cramped, allowing use of ordinary concrete; neither is its shape restricted by the location of the actual center of gravity of the counterweight mass, since

FIGURE 5. DOUBLE LEAF OVERHEAD COUNTERWEIGHT HIGHWAY BRIDGE OVER INNER HARBOR ENTRANCE, COPENHAGEN, DENMARK

Length span, 109 feet 2 inches; width roadway, 22 feet 7 inches; double track St. Ry.; width sidewalks, 10 feet 3 inches. Completed 1909

FIGURE 6. SINGLE LEAF OVERHEAD COUNTERWEIGHT HIGHWAY BRIDGE OVER COOPER'S CREEK AT FEDERAL STREET, CAMDEN, NEW JERSEY

Length span, 78 feet, width roadway, 34 feet; double track St. Ry.; sidewalks, 7 feet. Completed 1908

the correct counterbalancing effect is applied to the leaf at the counterweight trunnions, which are accurately located in the shop, insuring correct balance irrespective of the location of the actual center of gravity of the counterweight.

4. Operating machinery and motors are not located on the moving leaf but are securely supported on fixed girders anchored to the pier, providing a rigid support free from distortion, thus facilitating electrical connections, lubrication, inspection and maintenance. Likewise, hand-operation is more convenient and efficient.

5. The vital parts of movement, the trunnions, are securely housed in journal bearings, lined with phosphor bronze bushings, well lubricated, reducing wear to a minimum, and giving protection against influence of weather, lodgment of dirt, etc. *Trunnions in their bearings give surface contact with pressure distributed over requisite area for safe unit load.*

6. Counterweighting and operating mechanism readily applied for converting fixed spans into bascule structure with minimum alteration to existing structure.

7. Design lends itself to artistic treatment since counterweight may be designed as ornamental portal.

Osborne St. Bridge Winnipeg, Canada

Group II. Underneath Counterweight Type

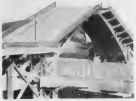


FIGURE 7, (a) and (b), illustrates the Underneath Counterweight Type, showing views closed and open of the Stutson Street Bridge over the Genesee River, at Rochester, New York, completed June, 1918. The counterbalancing principle in this type is the same as in the vertical overhead counterweight type described under Group I, and is shown diagramatically in Fig. 8. As the name implies, however, the counterweight and link are located underneath the roadway, which arrangement is not less advantageous than when placed above the roadway, and is best adapted for use where clearance between water level and under side of bridge is not too limited.

In the design illustrated, the bascule span consists of two symmetrical leaves. Two deck trusses for each leaf are used, each mounted on a trunnion just below the roadway, supported in symmetrical bearings secured to a pair of structural steel columns, or trunnion posts. These posts are directly supported over the center line of the channel pier and are part of an adjacent trestle-like approach span which also serves to support the operating machinery and operator's house, and transmits to the piers, the live load uplift at the extremity of the short arm of the leaf.

Each leaf is exactly balanced about the main trunnions, as in a single leaf design, but unlike the single leaf span, which is supported at both ends, there is no support at the ends of the leaves at the center of the span and, therefore, each must act as a cantilever span under live load. The live load on the long arm of the leaf will thus produce an uplift at the extremity of the short arm, referred to above as being transmitted to the piers through the agency of the adjacent approach span. This result is accomplished by providing the extremity of the short arm of each leaf truss with a bumping casting having an extended horizontal surface facing upward which comes into

Figure 7. (A) and (B) Double Leaf Underneath Counterweight Highway Bridge. Stutson Street Over Genesee River, Charlotte, Near Rochester, New York

[illegible] Span, [illegible] Roadway [illegible] Sidewalks [illegible] feet 6 inches. Completed 1918

bearing with the underside of a short transverse bumping girder, riveted to the longitudinal floor girders of the tower approach span, which latter frame into the trunnion posts and rear trestle bent whose bases are anchored to the piers.

While the live-load anchorage just described makes each leaf act in the main as independent cantilever spans, the trusses of each leaf are, nevertheless, locked together at the center where they meet. The purpose of this lock, primarily, is to cause the two leaves to deflect equally when either leaf carries live load and the other none; in this way there can be little or no relative vertical movement between the leaves under traffic. This center lock is motor driven, controlled from the operator's house and interlocked with the leaf motors. The operating mechanism is quite similar to that described in the vertical overhead counterweight type under Group I; the operation of both leaves is controlled from a single operator's house, showing at the right hand side of the illustration.

A characteristic feature of the underneath counterweight type is the absence of openings, or traps, in the roadway floor as the bridge opens. The break in floor, i. e., the dividing line between the floor on the fixed approach span and on the bascule leaf, is located in front of the main trunnions so that in opening the bridge no part of the floor revolves downward. The leaf itself, therefore, forms a positive barrier against traffic, thus preventing accidents similar to those occurring at the open ends of the ordinary drawbridge.

Figure 9 (a) and (b) illustrates a double leaf deck truss bascule bridge built across the Chicago River at Jackson Blvd., Chicago, Ill., completed 1916. This structure is another example of the

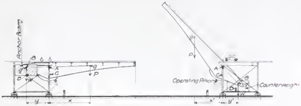


FIGURE 8. DIAGRAM UNDERNEATH COUNTERWEIGHT TYPE.

underneath counterweight type of Strauss Trunnion Bascule Bridge. The method of operation is quite similar to that of the bridge illustrated in Fig. 4, described above, the dead load of the leaf being balanced about the main trunnion, but the method of providing for the support of live load on the leaf differs, as follows: The bascule leaf when closed, comes to a bearing at a point on the substructure 10 feet ahead (toward center of span) of the main trunnion, a hinge-like casting being secured to the bottom flange of each bascule truss and a socket-like casting secured to a cast shoe anchored to the masonry, forming a means of support at this point. Under live load the leaf will, therefore, tend to lift up slightly from the main trunnion bearings, the live load support castings acting as a fulcrum for both the leaf and

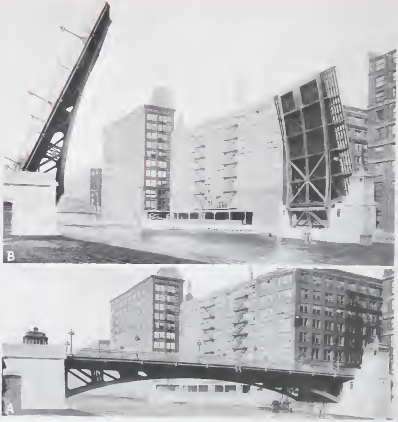


FIGURE 9 (A) AND (B) DOUBLE LEAF UNDERNEATH COUNTERWEIGHT HIGHWAY BRIDGE. JACKSON STREET OVER CHICAGO RIVER, CHICAGO, ILLINOIS

Length span, 202 feet, width roadway 37 feet, sidewalk 13 feet. Completed, 1916

counterweight. The increased moment arm of the counterweight (10 feet) thus gained, allows the counterweight to balance the live load as well as the dead load. A light anchorage, however, is provided at the extremity of the short arm of the bascule girders for maximum loads and bumping impact in closing.

Fig. 9 (c) illustrates one leaf of the Jackson Street bridge in course of construction. Both leaves were erected in the open position, without interfering with river navigation, with a minimum amount of false work—none whatever being required in the river. It was unnecessary to maintain highway traffic during the period of erection.

The detail of the support for the main trunnion bearings differs from that used in the bridge at Rochester, referred to above. By reference to Fig. 9 (c) it will be seen that both the inside and the outside trunnion bearings are supported on a transverse girder passing through the apertures in the bascule trusses and supported outside of these trusses. The web members and bottom chord of the trusses form a quadrilateral about the cross girder so that in operating, no interference is possible.

As referred to in the preceding pages under Group I, a double-leaf bridge can be designed to act as a three-hinged arch under live load, and the same applies to the underneath counterweight type, an example of which is the bridge across the Neva River at Petrograd (illustrated on the cover of this catalogue), a 209 foot span, with a 72-foot clear roadway, double track street car line, and two 9-foot 6-inch sidewalks. The bridge is an arched deck truss design in which the center hinge between the leaves is located just beneath the roadway, and the two end hinges are formed at the springing lines in the bottom chords by a casting secured thereto coming in contact with a casting anchored to the pier near the channel line. Means are provided to relieve the pressure of the counterweights at the tail ends of the trusses when the bridge is closed, to insure proper bearing at the three hinges.

The bascule span is flanked on either side by two steel arch deck approach spans, of approximately the same length, and with these forms a structure of ideal symmetry and beauty.

Fig. 10 (a) and (b) illustrates the underneath counterweight as applied to a single leaf design, showing views of the International & Great Northern Railway bridge over Buffalo Bayou, at Houston, Texas, completed in 1915. It differs in principle in no essential particular from the double leaf type.

The new structure replaced an old center pivot swing bridge, the old substructure being utilized, with modifications, to accommodate the bascule span. Timber trestle approaches are used at each end of the span.

Operation is manual with provision for future installation of power drive. The span is operated by a hand capstan, or turning lever, which engages the squared end of a vertical shaft

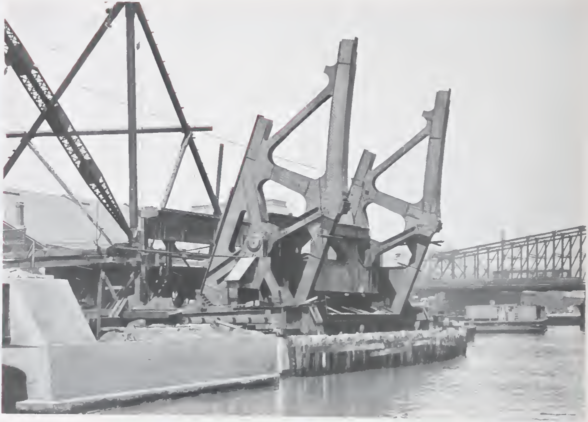


FIGURE 9(c). ERECTION VIEW, JACKSON STREET BRIDGE, CHICAGO

spans, either double or single leaf designs, as demonstrated in over a score of such bridges in service. Fig. 11 illustrates an example of double leaf underneath

at the center line of track on the deck of the approach over the counterweight. By means of bevel and spur gears, the power is transmitted to an operating pinion, mounted on a cross shaft turning in bearings secured to the base of the trunnion posts, which engage circular racks secured to the bottom flanges of the tail ends of the main girders.

The Strauss Trunnion Bascule Bridge is equally economical and efficient when used for short

FIGURE 10. (A) AND (B) SINGLE LEAF UNDERNEATH COUNTERWEIGHT BRIDGE. INT. & GRT. NOR. RY. OVER BUFFALO BAYOU, HOUSTON, TEXAS

Length span, 110 feet 6 inches; double track. Completed 1915

highway bridge, 66-foot clear span, over the East Chicago Canal, at 151st Street, Lake County, Indiana, completed in 1917. Fig. 12 (a) and (b) illustrates a similar design with concrete approaches, providing a 100-foot clear span, over the Calcasieu River, at Lake Charles, Louisiana, completed in 1916.

Fig. 13 illustrates the erection of a double leaf deck plate girder highway bridge at Port

FIGURE 12 (A) AND (B) SHORT SPAN DOUBLE LEAF UNDERNEATH COUNTERWEIGHT HIGHWAY BRIDGE OVER CALCASIEU RIVER, NEAR LAKE CHARLES, LA.

Length Bascule span [illegible] feet, approach spans [illegible] feet, width roadway [illegible] feet. Completed 1916.

FIGURE 11. SHORT SPAN UNDERNEATH COUNTERWEIGHT HIGHWAY BRIDGE OVER EAST CHICAGO CANAL AT 151ST STREET, EAST CHICAGO

Length Bascule span [illegible] feet, approach spans [illegible] feet, width roadway [illegible] feet, sidewalks [illegible] feet. Completed 1917.

Figure 13. Erection View Military Street Bridge over Black River, Port Huron, Michigan
(Photographed 1913)

Length span, 82 feet 6 inches, width roadway, 40 feet; double track street railway; sidewalks 12 feet 6 inches. Completed, 1914

Huron, Mich. The view was photographed while derricks located on the approach at either side of the channel were in the act of placing the last of the main bascule girders, after having picked it up from the scow in the river. As will be noted, each leaf has three main girders, and when all were in correct position, supported on the previously erected trunnion posts and bearings, the floor deck and counterweights were erected simultaneously. River traffic was not interrupted during erection and a temporary bridge for pedestrian traffic was built close by (showing at the right of this picture) with a moored scow, forming a section of the crossing, to permit navigation.

Fig. 14 (a) and (b) illustrates an important and attractive deck-plate girder bridge now being built over the Pequonock River at Stratford Ave., Bridgeport, Conn. The width of roadway is 55 feet clear between curbs, and in order to facilitate erection without interrupting traffic one-half of the bridge was built adjacent to the old swing bridge. The views here shown were photographed when the first half of the new bridge was placed in service, just after the old swing span was removed. A portion of the pier protection of the latter can be seen still remaining in the channel before final removal. This method of construction was made possible by designing each leaf to be supported by two pairs or bascule girders; however, when the structure is finally completed the roadway will be continuous and the two pairs of bascule girders will operate in unison. The building of the sub-structure was carried on in halves, the same as the superstructure.

Fig. 15 illustrates another underneath counterweight bridge, using deck trusses, completed in 1916, over the Christiana River, at Third St., Wilmington, Del. A feature of this design is the use of cassion-like reinforced concrete counterweight enclosures, serving as pits, supported by concrete brackets on the sides of the piers. The bottom of these enclosures is at low water elevation and they serve the purpose of preventing the counterweight becoming immersed during high water stages. This type of construction is much less expensive and more simple than the ordinary method of building a pier large enough to accommodate a pit within its confines.

* * *

The advantageous features of the Strauss Underneath Counterweight Type are summed up as follows:

1. The dead load of the bridge remains a fixed load on the foundation during operation of the bridge, an ideal condition for the design of the foundations.

2. Pivotal connection of the counterweight gives maximum moment arm for counterweight and in most cases eliminates necessity of a counterweight-pit in the foundations. For the same reason the shape of the counterweight is readily adapted to the available space beneath the roadway.

FIGURE 14. (A) AND (B) DOUBLE LEAF UNDERNEATH COUNTERWEIGHT HIGHWAY BRIDGE, STRATFORD AVENUE OVER PEQUONOCK RIVER, BRIDGEPORT, CONNECTICUT

Length of span, 155 feet; width roadway, 55 feet; double track street railway; sidewalks, 12 feet 6 inches.

3. Break in floor located in front of main trunnions precluding the possibility of the bridge opening under live load, likewise prevents the forming of an opening, or trap, in the floor through to the pit or stream as the bridge opens. (See Fig. 8, page 19.)

4. Motors and operating machinery located in readily accessible enclosures and secured to fixed supports which remain stationary during operation of bridge, facilitating electrical connections, lubrication, inspection and maintenance. Likewise, hand operation is more convenient and efficient.

5. The vital parts of movement, the trunnions, are securely housed in journal bearings lined with phosphor bronze bushings, well lubricated, reducing wear to a minimum, protected against influence of weather, lodgment of dirt, etc. *Trunnions in their bearings give surface contact with pressure distributed over requisite area for safe unit load.*

FIGURE 15 DOUBLE LEAF UNDERNEATH COUNTERWEIGHT HIGHWAY BRIDGE THIRD STREET OVER CHRISTIANA RIVER WILMINGTON, DELAWARE

Double Span Bascule, 172 feet, approach spans 110 feet 4 inches, width roadway 37 feet, double track street railway, sidewalks, 8 feet. Completed, 1916

Group III. Heel Trunnion Type

FIGURE 17 (a) and (b), illustrates one of the most recent examples of the Heel Trunnion Type, showing views of the Chicago & Northwestern Railway 3-track bridge over the Chicago River, at Deering Station, Chicago, completed July, 1916. The "Heel Trunnion" type derives its name from the fact that the leaf trunnion is located at the heel of the truss, i. e., at the point of intersection of the inclined end-post and bottom chord of the truss. The accompanying views, Fig. 16 (a) and (b), illustrates one of the main trunnion bearings before erection of the main truss and the trunnion and truss in place. This type was developed to meet the demand for increased size and capacity of bascule bridges and finds a large field of usefulness in railway service. The first bridge of this type was completed in 1910 on the line of the New York, New Haven & Hartford Railroad, across the Cape Cod Canal, at Buzzards Bay, Massachusetts.

FIG. 16B

Fig. 18 illustrates the principle of the design. (A) is the leaf trunnion, (C) the counterweight trunnion, and (B) and (D) the two link trunnions. A line drawn from (A) to the center of gravity (g), of the movable span is parallel and opposite in direction to a line drawn from (C) to the center of gravity (g^1) of the counterweight. This condition is maintained throughout the movement of the bridge by virtue of the paral-

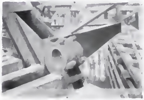


FIG. 16A

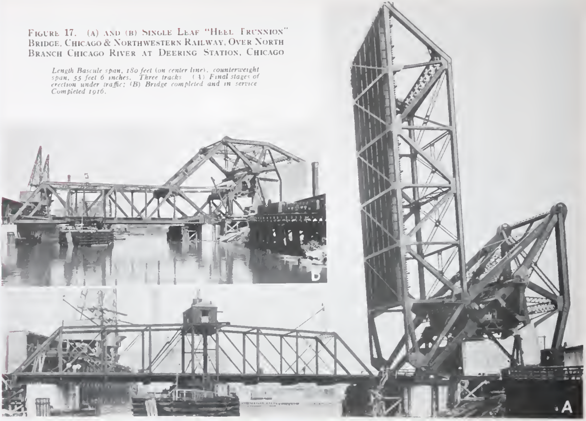


FIGURE 17. (A) AND (B) SINGLE LEAF "HEEL TRUNNION" BRIDGE, CHICAGO & NORTHWESTERN RAILWAY, OVER NORTH BRANCH CHICAGO RIVER AT DEERING STATION, CHICAGO

Length Bascule span, 180 feet (on center line), counterweight span, 55 feet 6 inches. Three tracks (A) Final stages of erection under traffic; (B) Bridge completed and in service Completed 1916.

lelogram (ABCD) and the weight of leaf and counterweight being inversely proportionate to their respective moment arms (x) and (y), the span is thus maintained in equilibrium in all positions.

One result of this arrangement is the separation of the supports for the leaf and counterweight, that is, pier No. III, under the vertical leg of the fixed triangular tower (ACE), supports the counterweight, and pier II, at the heel of the truss supports the moving leaf, the dead load on the rest pier, No. I, being zero since the leaf is always balanced. This arrangement avoids the concentration of the dead load reaction on any one trunnion and on the foundations, which in the large, modern bridges would reach enormous proportions. Moreover, the dead load reactions are vertical and constant for any position of the bridge.

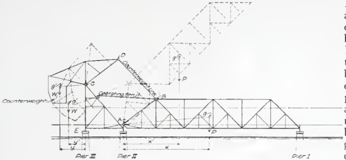


Fig. 18. Diagram Heel Trunnion Type.

The bridge is operated by means of rack and pinion drives. The racks are secured to the bottom of a pair of rigid members termed, "operating struts," one for each truss, one end being pivoted to the leaf truss at the hip, the rack being engaged by the operating pinion, which, together with the electric motors and intermediate gears, is located in the portal of the counterweight tower (ACE). The dotted lines indicate the position of the bridge when open.

This design is a radical departure from anything that had been attempted in bascule bridge construction in recent years. Referring to Fig. 17, the leaf trunnion, as already pointed out, is located at the heel of the truss. In the design illustrated, the trunnion bearing itself is secured to the gusset plates of the truss and turns on a trunnion pin fixed to the base of the triangular approach tower, termed the "Counterweight Tower." The main members of this counterweight tower and the main members of the leaf truss are in line, so that only a single bearing and pin for each truss is required. In other designs of this group, the pin is secured to the truss and the bearing to the tower. (See Fig. 16 (a) and (b).) In like manner, the counterweight truss is mounted on trunnions at the apex of the tower, except that the trunnion is secured to the counterweight truss, which turns in

symmetrical bearings, one in line with the tower post and the other supported on a short cantilevered girder just outside of the tower post. Double bearings are used on account of the wing counterweight construction referred to below.

As will be noted, two concrete counterweights are provided, which are termed "wing counterweights," one for each truss. The double requirement of building this bascule bridge without interrupting railway traffic over the old swing bridge, which it replaced, and without interrupting river traffic, gave rise to the development of the wing counterweight system, which led to the disclosure that this type of construction is also economical under favorable conditions irrespective of the above requirement. A single concrete counterweight block extending the full width of the bridge had been used in previous designs and is still used in locations where conditions are unfavorable for the wing counterweight construction. The position of the single counterweight when the bridge is open is limited by the elevation of the top of rail. (See Fig. (18).

Since it is necessary for the wing counterweights to move entirely outside of the railway clearance, to permit the passage of trains, they operate beyond the range of the railway tracks. In opening, therefore, their movement is not limited by the elevation of the top of rail and the moment arm of the counterweight is determined rather by the elevation of high water than by the dimensions of the bridge, and when the bridge is open the counterweights descend below the roadway, their lowest point being 20 feet below the top of rail, just above high water. The moment arm of the counterweight is thus increased without increasing the height of tower, with consequent saving in the volume of concrete and weight of structural steel. The counterweights are reinforced and efficiently supported by members of the counterweight trusses imbedded in them, and the counterweight trusses are thoroughly braced together.

The operating motors, controllers and machinery are located in the portal of the tower, and as the counterweights do not obstruct the view of the railway tracks the bridge operator and the train signal operator are located under the same roof as the motors and machinery. An emergency gasoline engine is also located in the machinery house for use in case the electric supply current is interrupted or in case of accident to the electric machinery. In addition to the solenoid motor brakes and band brakes for the gasoline engine drive, an emergency air-operated brake acts directly on each operating strut, totally independent of the operating machinery. Thus, if an accident should happen to any of the intermediate gears or shafts between the operating pinions and motors, this direct-acting brake will hold the bridge against possible movement. Likewise, it can be used in conjunction with the other brakes under ordinary conditions and can be used to lock the bridge in any position.

When the bridge is closed the leaf is locked to the pier at the front end by means of a motor-driven latch bar in the bottom chord of the truss,

FIGURE 20. SINGLE LEAF HEEL TRUNNION HIGHWAY BRIDGE OVER CATARAQUI RIVER, KINGSTON HARBOR KINGSTON, ONTARIO
Length Bascule span, 170 feet; counterweight span, 42 feet; width roadway, 24 feet; sidewalk, 4 feet. Completed, 1917

which enters a suitable casting, secured to the bridge shoe anchored to the pier. This lock, together with the main operating machinery, is interlocked with the train signals so that the bridge can not be unlocked or operated while the signals for approaching trains are set at Clear, and likewise train signals are held at Danger until the bridge is firmly closed and locked.

As already referred to, it was necessary to erect this bridge without interruption either to railway or river traffic. The Heel Trunnion Type is admirably adapted for these severe requirements.

Fig. 17 (a) is a view photographed just before the bridge was placed in operation. It shows the old swing bridge still in place and relative positions of the old and new piers. The leaf was erected in the open position, the end panel of the floor system being omitted, but otherwise the entire leaf, counterweight and tower, machinery, etc., was completed while the old swing bridge remained in service. At this stage of completion of the bascule, the old swing bridge was swung open and the center panels quickly cut out by the oxy-acetylene torch; simultaneously the end floor panel of the bascule was put into place and the new bridge was thus placed in service with only a few hours' delay. Afterward, the remaining parts of the old swing bridge and piers were removed at leisure. The bascule type of bridge lends itself readily to erection in the open position, and for this reason, where false work in the stream is difficult and expensive, the bridge is often thus erected in preference to the usual method of bridge erection.

Fig. 20 illustrates a Heel Trunnion Highway bridge, being the bascule span of the causeway across Kingston Harbor, Kingston, Ontario, completed April, 1917. In principle, the design is the same as for the Railway Type described above. It will be noted that a single counterweight is used, there being no particular advantage in using wing counterweights on account of, among other considerations, the close proximity of water level to the bridge floor. Attention is also called to the architectural treatment of the design, which is sometimes a more important consideration in Highway than in Railway bridges.

Fig. 21 (a) and (b) illustrates a double leaf heel trunnion highway bridge across the Sacramento River at Walnut Grove, California, completed July, 1916.

A unique feature of this design is the method of supporting the live load on the bascule leaves, which act as cantilevers, having no connection at the center other than the bottom chord lock, capable only of equalizing the shear between the two leaves. The operating strut in this design serves also as an anchor arm, the location of which in relation to the leaf and tower suggests its use for this joint purpose. It only remained to design this member to carry the tension stress induced by the maximum live load on the leaf and to devise a satisfactory detail for anchorage to the tower span when closed and yet to disengage readily when the bridge opens, which is accomplished in the manner described as follows: The tower extremity of the strut has an 8 inch turned pin secured to it by means of two collars with flanges riveted to each web of the strut. This pin projects beyond the webs far enough to carry irregular hexagonal nuts (similar to Lomas nuts), having radii of slightly varing lengths, any side of which can be made to bear against the rear surface of the apex of the tower, which is normal to the center line of strut when the bridge is closed. The hexagonal nuts permit the anchor strut to be lengthened or shortened during erection, so that an exact adjustment between the leaves

FIGURE 21. (A) AND (B) DOUBLE LEAF HEEL TRUNNION HIGHWAY BRIDGE OVER SACRAMENTO RIVER, WALNUT GROVE, CALIFORNIA

Length Bascule span, 226 feet; approach spans, 57 feet; width roadway, 18 feet. Completed, 1916.

Operating strut acts as live load anchor

and struts can be effected. The nuts are secured in their final position by means of a set-screw keying the collars, riveted to the webs of the strut, to the pin to which the nuts are secured. After the erection of the bridge was completed and the leaves first lowered, they met at the center within three-eighths of an inch of the same elevation. By adjusting the anchor arms by means of the device above described, the leaves were brought to exact position in relation to each other.

In locations where a right-angled counterweight tower, while serving the needs of the crossing from the standpoint of a movable span, would not afford the most economical arrangement as regards length of approach spans and location of piers, the shape is altered to accommodate both.

In the instance of the Sacramento River bridge, the counterweight tower is in the shape of an isosceles triangle, which makes it the proper length for economical design, without sacrificing its effectiveness from the standpoint of an operative bridge. In some structures, as, for instance, the Thames River bridge for the New York, New Haven & Hartford Railroad (illustrated in Fig. 22), the counterweight is carried entirely on the 327-foot approach span, thereby obviating the necessity of building two piers near the channel, where the water is over 100 feet deep. The piers were built large enough to provide for the future erection of a duplicate bridge immediately adjacent.

* * *

Other striking developments of the Heel Trunnion type are cited, as follows:

1. The 235-foot single-leaf double track B. & O. R. R. bridge over the Calumet River, South Chicago, completed in 1913, which holds the record for the longest single-leaf bridge in service. This length is now exceeded, however, by the double track heel trunnion bridge, 260 feet in length, over the Chicago River at 16th Street, for the Illinois Central, Chicago & Northwestern, Michigan Central and the Chicago, Burlington & Quincy railroad companies.

2. The 186-foot, single-leaf, double deck Highway, and double track railroad bridge illustrated in Fig. 23 built by the Canadian Pacific Railway over the Kaministiquia River at Fort William, Ontario, completed in 1914, being the first double deck bascule bridge ever undertaken, and involving new problems in design.

In the design illustrated the counterweights are located at either side of the trusses between the upper and lower decks, and as shown do not descend below the surface of the water in its extreme position. In a higher level bridge where appreciable clearance exists between the under side of bridge and the water surface, or where a counterweight pit is not too objectionable, the counterweight can be located entirely below the lower deck and the counterweight trusses will not extend above the upper chord of the main trusses, producing a structure free from any criticism as to appearance.

3. The double-leaf simple span single track railway bridge across the new U. S. Ship Canal

at Sault Ste. Marie, Michigan, on the Canadian Pacific Railway, completed 1913, illustrated in Fig. 24. This bridge possesses the following novel features:

(a) When closed, chord locks convert the two leaves into a single span.

For railway bridges, the double leaf, cantilever design, with live load anchors or supports, as used for highway bridge, is often objectionable, on account of the extremely heavy anchorages and the deflection and play at the center of the span under heavy concentrations. By building two heel trunnion leaves adapted to interlock automatically at the center, a single simple span is obtained of a length in this particular design of 336 feet between channel piers. The possible feasible length of span for this type of structure is just double the length of the maximum single leaf span and since a single leaf 260-foot span (16th Street, Chicago) is now being built, it will be realized that a double-leaf span 520 feet in length is altogether practical.

FIGURE 22. SINGLE LEAF HEEL TRUNNION BRIDGE, NEW YORK, NEW HAVEN & HARTFORD RAILROAD OVER THAMES RIVER, NEW LONDON, CONNECTICUT

Length of span, 188 feet; counterweight approach span 327 feet; double track. Completed, 1910

Note use of single trunnion pier and approach span supporting counterweight. Piers built for future duplicate bridge adjacent

The chord locks are automatically operated by the movement of the leaves themselves and are extremely simple in design and direct in action. Five years' service has developed no imperfections or failure of any kind. While the lower chord lock is designed primarily for tension stresses, temperature stresses impose the necessity of providing for compression as well; the absence of adjustable parts in the lock itself relieves the mechanism from complicated details, and movement under temperature variation is taken up entirely independent of the lock, as referred to in the following paragraphs.

(b) The counterweight tower at one end of the span is mounted on roller bearings, permitting expansion and contraction of the bridge when closed, due to temperature variation.

FIGURE 23. DOUBLE DECK SINGLE LEAF HEEL TRUNNION BRIDGE
CANADIAN PACIFIC RAILWAY OVER KAMINISTIQUIA RIVER, FORT WILLIAM, ONTARIO
Length Bascule span, 186 feet, counterweight span, 40 feet, double track steam railway, lower deck, upper deck 29 foot clear roadway double track electric railway. Completed, 1914

The length of the superstructure, including counterweight tower, is 426 feet over all, allowance for expansion and contraction of which is made by supporting one counterweight tower entirely on roller bearings, permitting one end of the span to move longitudinally when the bridge is closed. This provision is made possible by the divided

dead load reactions and the vertical and constant character of same. The tower is locked before the operation of the leaves is commenced.

(c) It is the longest bascule bridge in the world.

The distance center to center of channel piers, 336 feet, is the record length for a bascule bridge and as already referred to, points the way to still longer spans. It is generally conceded that for highway traffic the problem of satisfactory

FIGURE 24. DOUBLE LEAF HEEL TRUNNION BRIDGE, CANADIAN PACIFIC RAILWAY (SINGLE SPAN DESIGN) OVER NEW U. S. SHIP CANAL, SAULT STE MARIE, MICHIGAN

Length Bascule span, 336 feet; counterweight spans, 45 feet; single track. Completed, 1913. Longest Bascule bridge in world

long spans is not as difficult of solution as for railway traffic, since the concentrated live loads are not nearly as great, as referred to above, and the cantilever type, for such lengths as have hitherto been required, has been found satisfactory. The success obtained in this long span railway bridge, therefore, makes possible the use of highway spans in excess even of the present rather high limit of the cantilever type.

(d) It is, perhaps, the most important bascule bridge in service, from a navigation standpoint.

Not only is this bridge the longest bascule bridge in the world, but likewise it crosses one of the world's most frequently navigated channels, the new canal connecting Lake Superior with the lower Great Lakes, generally known as the New U. S. Ship Canal, the construction of which was undertaken to accommodate two enormous twin locks 1,350 feet long by 80-feet wide. These new locks, in conjunction with the canal and two parallel existing smaller locks, form a feature of the Inland Navigation System of the Great Lakes, and at this point passes 75% of all the traffic on the Great Lakes. The canal and locks enable lake vessels to pass the rapids of the St. Marys River, which is the connecting link between Lakes Superior and Huron, and is 64 miles long. The Rapids at Sault Ste. Marie are about three-quarters of a mile in length and have a fall of from 17 to 21 feet.

This bridge is a link in the International bridge across these waters between the United States and Canada, and is located about 1,000 feet west of the entrance to the new locks. The bascule bridge must be opened for all ships entering or leaving the locks during the open season of navigation, lasting 8½ months, and the average number of bridge operations during this period is 3,626. The fact that a greater yearly tonnage passes through the canals and locks at Sault Ste. Marie than through either the Panama or the Suez canals, will give a commensurate idea of the great importance of this bridge.

* * *

Reference has already been made to the method of erecting the heel trunnion type in the open position for the C. & N. W. Ry. Another example where the bascule span was erected in the open position is found in the Great Northern Ry. bridge over the entrance to the Lake Washington Canal at Seattle, Washington, illustrated in Fig. 25.

In this case it was unnecessary to maintain railway traffic and it was not particularly essential to maintain navigation, but the advantage and economy of dispensing with false work in the channel were sufficiently important to weigh in favor of erecting the bridge in the manner illustrated. A view of the bridge in the final stage of completion is shown on the frontispiece of this catalogue.

Fig. 26 illustrates the erection of the Erie R. R. bridge over the Cuyahoga River at Cleveland, Ohio, without interruption to railway traffic over the existing swing bridge which it replaced.

The new bridge was built in the open position, the counterweight being designed to clear the railway traffic in the open position (illustrating the method in use before the development of the wing counterweight system previously described); the sections of the trusses and floor system were hoisted into place by a cable operated derrick secured to the portion of the structure already built and moved up as the work progressed. To facilitate construction, the railroad, though a double track line, operated its trains on a single track at the bridge site.

As previously noted, it is not always advantageous to build a bascule bridge in the open position, Fig. 27 illustrating the method of building the Northern Pacific Railway bridge in the closed position, over the Dwamish River at Seattle, Washington. In this instance, it was unnecessary to maintain navigation, as the channel had not been fully dredged. The bridge was built on timber false work and a temporary "run around" pile trestle carried the railway traffic during erection of the new bridge.

* * *

Figure 25. Erection View Great Northern Railway Bridge over Entrance to Lake Washington Canal, Seattle, Washington

Length span, long truss, 206 feet 7 inches; short truss, 193 feet 5 inches; counterweight span, 50 feet. Double track. Photo taken November, 1913. Completed 1914

The advantageous features of the Strauss Heel Trunnion Type are summed up as follows:

1. Moving leaf and counterweight mounted on separate trunnions, reducing concentrated loading on a single trunnion.

2. Moving leaf trunnions located at heel of truss supported at foot of triangular counterweight (or approach) span, giving maximum clear channel for navigation, with minimum span length.

3. Counterweight trunnions mounted at apex of triangular counterweight (or hip of approach) span, allowing space for counterweight above roadway, entirely obviating use of pits in substructure.

4. Triangular counterweight tower supported on two piers. One pier reaction equalling weight of moving leaf and the other equalling weight of counterweight. These dead load pier reactions are constant and vertical for all positions of bridge—avoiding necessity of either pier supporting combined weight of leaf and counterweight.

5. The separate support of leaf and counterweight and constant and vertical character of the pier reactions (referred to in 4) are ideal conditions for inexpensive and safe design of the substructure, especially where piers are founded on piles.

FIGURE 26. ERECTION VIEW ERIE RAILROAD BRIDGE OVER CUYAHOGA RIVER, CLEVELAND, OHIO
Length span, 180 feet—double track Photo taken August 1911 Bridge completed October, 1911

6. When counterweight support at hip of approach span single pier can be used whose dead load reaction is the vertical resultant of leaf, counterweight and one-half approach span. Dead load of leaf and counterweight remains dead load during operation of bridge, thus live load on approach span not increased. Single pier construction advantageous where long approach spans are required and where water is very deep.

7. Motion of leaf rotative only, about center located at roadway level close to top of pier. Furthermore, leaf directly anchored to pier through medium of trunnion and trunnion bearings, giving maximum stability and minimum wind arm. Center of rotation being located at roadway level avoids opening or gap in floor as bridge operates.

FIGURE 27 ERECTION VIEW NORTHERN PACIFIC RAILWAY BRIDGE OVER DWAMISH RIVER, SEATTLE, WASHINGTON

Length bascule span 10[illegible] feet. Counterweight span 42 feet. Single track. Photo taken April [illegible] Bridge completed June [illegible]

8. Leaf trusses in line with counterweight span, or approach span, requiring only single bearing for each truss and trunnions no longer than width of truss chords.

9. The vital parts of movement, the trunnions, are securely housed in journal bearings lined with phosphor bronze bushings, well lubricated, reducing wear to a minimum, protected against influence of weather, lodgment of dirt, etc. *Trunnions in their bearings give surface contact with pressure distributed over requisite area for safe unit load.*

10. Operating machinery located in portal of counterweight or approach span motors and

bearings secured to fixed supports, facilitating installation, electrical connection, inspection and maintenance.

11. System of counterbalancing permits economical use of "wing" counterweights, one on each side of bridge, moving outside the range of bridge traffic, allowing economical erection of bridge in open position, on same center line as old bridge, without interference with bridge traffic or navigation.

12. Wing counterweights further allow operator to be located under same roof with motors and operating machinery, without obstructing his view from either the roadway or the stream.

Passaic River Bridge Belleville, N. J., Hudson, Bergen and Essex Counties

Group IV. Direct Lift Type

THE Strauss Direct Lift Bridge is so designed that the moving span in opening and closing travels vertically only, the floor of the bridge remaining in a horizontal position throughout operation. In other words, the movement is the same as in an elevator in a modern building, except that no cables are used in any part of the mechanism. Therefore, so far as the bridge span itself is concerned, the movement is quite dissimilar from that of a bascule bridge, although the counterbalancing and operating systems are quite similar to those employed in the various Strauss designs described in the preceding pages.

The direct Lift Bridge is economical where low vertical clearance, above water, is required for navigation or where the span is long. Fig. 28 illustrates the principle of the design, which comprises a simple span (S), over the navigable channel connected to a counterbalancing mechanism mounted on two vertical tower posts (R), supported on piers at each end of the span, and operating mechanism comprising four motor or hand driven pinions at each corner of the span, which engage vertical racks secured to the posts (R).

The counterbalancing device at each end comprises a truss (F) mounted on the main trunnion (T) at the top of post (R), one end being pivotally connected to the hip of the main span (S), through the agency of the hanger (H) and carries at its other extremity two independent concrete counterweights. The larger counterweight, above, is pivotally connected to (F) at the base and at the top is pivotally connected to the upper extremity of (H) by means of the member (BD), termed the counterweight link (L). The pivotal points (ABCD) form a parallelogram and the point (T) is located in the side (AC) of this parallelogram. The secondary counterweight is rigidly connected to (F) and its only function is to bring the center of gravity of the truss (F) into the fulcrum (T) so that (F) within itself is always in equilibrium about (T).

Considering the bridge in a partially open position (shown at the right of the diagram), the forces acting vertically to the left of fulcrum (T),

which must be counterbalanced, are:

P_1 = weight of ½ of the main span (S) applied at (E).

P_2 = weight of the hanger (H) applied at its center of gravity (h).

P_3 = weight of ½ of the counterweight link applied at (B).

Consider the three vertical forces P_1, P_2 and P_3 replaced by a single vertical force (P) equal in magnitude and applied at (G), so located that the moment of (P) about (T) will equal the summation of the moments P_1, P_2 and P_3 about (T) and it then remains to locate a vertical force at a point on the side (CD) of the parallelogram (ABCD), whose moment about (T) will be opposite and equal thereto. To find the point on (CD) where this counterbalancing force should be applied, draw a straight line from point (G) through (T) until it intersects the line (CD) which point is marked (g); however, there is a vertical force (W_2), being ½ the weight of (L), applied at (D,) and therefore a vertical force (W_1) must be applied at (g^1) so located on (CD) that the resultant force (W), of (W_1) and (W_2) will fall at point (g) and of such magnitude that the moment of (W) about (T) will be equal and opposite to the moment of (P) about (T). The center of gravity of the concrete counterweight is therefore located at (g^1).

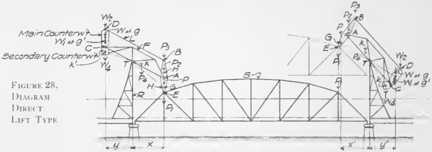


FIGURE 28. DIAGRAM DIRECT LIFT TYPE

The similar triangles (TAG) and (TgC) remain similar during the operation of the bridge by virtue of the parallelogram (ABCD) and, therefore, the horizontal moment arms (x^1) and (y^1) of the constant vertical forces (P) and (W) will always bear the same relation to each other and the bridge is in perfect balance for any position.

Fig. 29 (a) and (b) illustrates a Direct Lift Highway Bridge built by the United States Government over the Louisville and Portland Canal at

FIGURE 29. DIRECT LIFT HIGHWAY BRIDGE, U. S. GOVERNMENT, OVER LOUISVILLE & PORTLAND CANAL AT 18TH STREET, LOUISVILLE, KENTUCKY

Length lift span, 210 feet; approach spans, 85 feet and 75 feet; width roadway, 16 feet, vertical travel, 40 feet
(A) Bridge closed; (B) bridge open. Completed, 1915

Louisville, Kentucky, completed in 1915. The span is 210 feet long and its vertical travel is 40 feet in one direction. The clear width of roadway is 16 feet. The tower spans also serve as approach spans, one 75 and the other 85 feet in length. The bridge was erected in the open position and the counterweight trusses facilitated, to a large extent, the erection by the cantilever method.


B


A

FIGURE 18 — DIRECT LIFT HIGHWAY BRIDGE — COUNTERWEIGHTS BENEATH ROADWAY OVER RIDEAU CANAL AT PRETORIA AVENUE, OTTAWA, CANADA

Length [illegible] span, [illegible] approach span, [illegible] feet 6 inches, width roadway 44 feet, sidewalks 6 feet, vertical travel, [illegible] feet. Completed [illegible]

As already referred to, the main span is operated by four pinions, located at each corner of the span below the floor deck, engaging fixed vertical racks secured to the outside faces of the tower posts. These operating pinions are actuated through shafting and intermediate gears, by two 11 horse power electric motors located near the transverse center line of the span and controlled from an operator's house at the center of the span, suspended from the top chords above the traffic clearance line. One minute's time is consumed in fully opening or closing the bridge. Emergency hand operation is also provided by two turning levers at each end of the span in the center of the roadway. Indicators are installed in the operator's house consisting of red and white incandescent electric lights showing the various positions of the bridge. The operating motors are automatically cut out by the movement of the span when within 6 feet of the fully open or fully closed position, but a spring switch is located in the operator's house which, if held closed will render the automatic cut-outs ineffectual, enabling the bridge tender to further operate the bridge. Electrically operated safety gates are provided on the approach roadway at either end of the lift span, controlled from the operator's house and electrically interlocked with the lifting motors so that the latter cannot be operated until the gates are closed and the gates cannot be opened again until the bridge is firmly closed.

A unique application of the Strauss Direct Lift principle is exemplified in the Pretoria Avenue bridge across the Rideau Canal at Ottawa and completed in 1918, illustrated in Fig. 30 (a) and (b). It will be noted the counterbalancing and operating mechanism are located entirely below the floor of the bridge. This is made possible by placing the longitudinal center lines of the counterweight trusses at right angles to the longitudinal center line of the bridge, thus utilizing the piers to support and conceal the counterweight, etc. This type of construction is most feasible where the vertical travel is limited—in this instance being 20 feet.

* * *

Summing up, the advantageous features of the Strauss Direct Lift Bridge are as follows:

1. The design is economical for long spans with low vertical clearance for navigation.
2. Its component parts are directly connected by non-flexible members.
3. It is economically and exactly balanced. The operating motors are, therefore, not required to do work against the dead weight of any part of the structure, eliminating power waste.
4. The main elements of movement, the trunnions, are completely enclosed and protected from the weather, dirt, etc., reducing maintenance to a minimum.
5. The use of the counterweighted levers permits support of the span at intermediate points, reducing the dead load stresses and facilitating erection.
6. All parts of the structure are of equal longevity, obviating costly renewals.

Comparison of Bascule With Horizontal Swing Bridge

There are, and always will be, conditions where the swing bridge can be advantageously used, but it is no longer safe to assume that the bascule is not the cheapest and best solution even where in past years the reverse has been the case. For instance, in a broad river, where approach spans are required on either side of the channel, it is still maintained by some that there could be no economy in anything other than the swing. However, if the water is deep and the foundations difficult, the saving in substructure and draw protection possible in the bascule may so far outweight any economy of the swing in the superstructure as to leave the advantage with the former.

In general, the advantages of the bascule over the swing may be summed up as follows:

1. The center pier and draw span protection of the swing bridge are eliminated. These are especially objectionable in narrow channels, causing eddying currents, hindering navigation, and obstructing the flow, while the draw protection, if not maintained, causes damage to passing boats, with resultant expensive lawsuits.

2. Future addition of immediately adjoining bridges or additional tracks on either or both sides of existing bascule bridges is obtainable, which is impossible in case swing bridges are used.

3. For small vessels, the bascule need only open far enough to give sufficient vertical clearance, whereas the swing bridge must be opened fully in any event. The reason for this is that the entire width of navigable channel must be clear to permit passage, which is obviously impossible if the swing bridge be only partly opened.

4. As a corallary it follows that a quicker passage of vessels and resumption of traffic results than with the swing bridge.

5. In a double-leaf bridge the bascule offers an effective barrier against highway traffic going off the roadway into the river, a class of accidents common with the swing bridge.

5. The bascule can be erected without interruption to land or water traffic.

7. The bascule does not encroach on adjacent property or docks and does not isolate the operator from shore when open.

8. In railroad bridges, mitered rail joints can be used without the necessity of rail-lifting devices.

9. All stresses are statically determinate; ordinarily in the swing bridge continuous beam action takes place.

Operating Equipment and Safety Devices

While the operating equipment and safety devices have already been touched upon in the preceding pages, it will be of further interest to summarize and elaborate somewhat upon these important features as applying in general to all STRAUSS Bridges.

Figure 31. Interior of Operator's House, Chicago & Northwestern Ry. Three Track Bridge Over Chicago River, Deering Station.

"Operating Equipment and Safety Devices," comprise the following main items:

1. Operating machinery.
2. Brakes.
3. Locks.
4. Bumpers and Buffers.
5. Operator's House and Controls.
6. Gates and Signals.
7. Roadway Floor.

The above embody special features, suggested by our experience and practice, which contribute materially to the ease and safety of operation and to the general efficiency and economy of the bridge as a whole.

1. OPERATING MACHINERY. The operating machinery comprises a prime mover, geared to an operating

rack, attached to each truss, or girder, of the moving leaf and connected through an equalizer in order to produce an equal pull at the points of attachment to the movable leaf. The operating machinery is usually symmetrical about the longitudinal center line of the bridge. Cast steel gears, with cut teeth, reduce friction and give the best operating results.

The operating rack, either straight or curved, as above referred to, is attached to the moving leaf, but the operating machinery of all Strauss bascule bridges built in recent years is located on a stationary part of the bridge, suitably housed, adjacent to or under the same roof with the operator. Fig. 31 illustrates the interior of the operator's house of the Chicago & Northwestern Railway 3-track bridge, illustrated and described on pages 29 to 39. In addition to the bridge operating machinery, the house also contains the interlocking machine for all tracks leading to the bridge. This ideal location and support of the operating machinery permit accurate alignment of the bearings and shafting and the free and ready inspection and care of the machinery, independently of the movement or position of the leaf, and permit the electrical connections to be more readily installed and maintained.

In Strauss Direct Lift bridges, the operating machinery is located on the lift span and the rack is secured to the towers, but the machinery remains in a horizontal position throughout movement and, therefore, is not objectionable.

The driving power is generally furnished by electric motors, but where electric power is not available direct gasoline engine operation or electric motors supplied from a gasoline generator set, with storage battery, is provided. For the smaller bridges, where operation is not too frequent, hand power operation is used, with satisfactory results.

As secondary, or emergency power equipment, in case the main source of power is cut off, direct gasoline engine drive or a gasoline generator set to supply current for the main motors, or hand operation, is used. Where two independent electric power lines are available, other secondary power equipment may be omitted.

The operating machinery is designed to overcome the friction, inertia and the wind and the normal speed of opening or closing averages from 1 to 2 minutes. The secondary or emergency equipment is usually designed to operate the bridge in slower time since its use is infrequent.

2. BRAKES: Strauss bridges are equipped with both service and emergency brakes for arresting the movement of the bridge. The service brakes are used under ordinary conditions and the emergency brakes, as the name implies, are used for extraordinary conditions, as for instance, any failure of the service brake in case of an unusual unbalanced load on the bridge such as snow or a high wind.

The service brakes on electrically operated bridges are usually operated by a solenoid, i. e., an electro-magnetic device. They are usually manufactured and furnished by the makers of the standard types of electric motors and are mounted

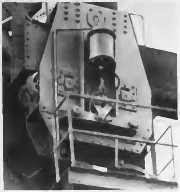


FIGURE 32

on the shaft of the motors which operate the bridge. When the motor current is shut off, the brakes set automatically, but a switch is provided in the operator's house to release them at will and allow the bridge to coast.

In bridges operated by gasoline engines or hand power and in some electrically operated bridges, hand brakes are used in place of the solenoid brakes.

Emergency brakes are operated either by solenoid, compressed air or by weighted levers.

The solenoid emergency brake is mounted on an intermediate gear shaft as close to the operating pinion as convenient in order to insure as direct action as possible, without depending on the intermediate gears and shafts; moreover these intermediate gears and shafts are thus relieved of consequent excessive braking stress. While the emergency brake is designed to set automatically in case the electric power is cut off either by accident or during normal process of operation, it can be kept out of action at the will of the operator.

The air operated emergency brake acts entirely independently of the operating machinery and is best adapted for use on our larger and heavier bridges. Fig. 32 illustrates this type of emergency brake on the Delaware, Lackawanna & Western R. R. (heel trunnion) bridge at Buffalo. The braking force is applied directly on the flanges of the operating struts, the brake mechanism being mounted on the operating strut guide. Fig. 33 illustrates a similar installation on the Great Northern Railway (heel trunnion) bridge at Seattle, Washington. The brake shoes are made to grip the top and bottom flanges of the operating strut by opening a valve in the operator's house which admits compressed air into the cylinder secured to the side of the operating strut guide. The piston rod of this cylinder is connected to the brake shoes for the bottom flanges of the strut by means of toggle levers and thus enough move-

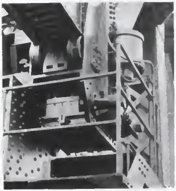


FIGURE 33


A

a pedestal casting bolted to the shoe. The lock can also be operated by hand.

In double leaf cantilever bridges, a motor driven lock is provided at the center of the span which holds the leaves in true alignment and further causes them to deflect equally under live load, reducing relative vertical movement between the ends of the leaves to a minimum. The lock is further designed to allow adjustment so that any wear due to longitudinal movement can be readily taken up. The opening and closing of the lock are independent of the opening and closing of the leaves, i. e., the leaves do not have to be operated simultaneously either to unlock or to lock them. If, therefore, the operating machinery for one leaf should become deranged, or if it becomes otherwise necessary to place one leaf out of commission, no delay or special provision is necessary to unlock the leaves.

The center locks of the Canadian Pacific Ry. International Bridge at Sault Ste. Marie, Michigan (see page 39), convert the two leaves into a single span when closed. These locks—compression locks in the top chords and tension locks in the bottom chords—are simple and direct in action and their use is, in part, responsible for the successful operation of this double leaf railroad bridge of a span length, 336 feet between trunnions, hitherto considered impractical and now holding the record for the longest bascule bridge in the world.

Rail Locks and Rail lifting devices are not required in Strauss Bridges. The rails on the moving section join with those on the fixed section either by means of dovetail castings or mitered joints. The movement of the rail is integral with the leaf and no separate moving parts in the joints are required.

4. BUMPERS AND BUFFERS: Bumpers are provided to finally arrest the movement of the span in opening, if for any reason either the service or emergency brakes fail. They consist of oak blocks backed by stiffener angles and plates, and in the heaviest bridges by springs, secured to a fixed portion of the bridge against which the truss or girder of the moving leaf bears at the extreme open position of the leaf.

A buffer is provided in our heavier bridges to absorb shock in closing the bridge. It consists ordinarily of a pneumatic cylinder, secured to the front end floor beam at the center line of the bridge, the piston rod of which strikes a metal plate bolted to the pier. The piston thus compresses the air in the cylinder, the pressure of which is regulated by an exhaust valve in the cylinder head. In opening the bridge the piston rod projects itself by gravity, the air having free egress from the bottom of the cylinder. This device may be partially seen in Fig. 34 (a).

5. OPERATORS' HOUSES AND EQUIPMENT: The Operator's house contains all the apparatus for the complete control and operation of the structure. This includes the electric switchboard on which is mounted the main and secondary switches, circuit breakers and recording instruments, the controllers for the main leaf motors, controllers for the motors, levers or con-

trolling valves for the brakes, controllers for roadway and sidewalk gates, indicators showing successive positions of the bridge and siren or whistle, for signalling navigators. Fig. 35 illustrates an interior view of an operator's house of the Jackson Street Bridge, Chicago (see page 20), and Fig. 31, already referred to, illustrates an interior view of the operator's house of the Chicago & Northwestern Ry. bridge at Deering, Chicago. (See pages 29-34). In the former, the operating machinery proper is located beneath the roadway, in the latter, both the operating machinery and interlocking mechanism for the railway tracks are located in the operator's house itself.

FIGURE 35. INTERIOR OPERATOR'S HOUSE, JACKSON STREET BRIDGE OVER CHICAGO RIVER, CHICAGO

Frame houses are the least expensive, though there has been a tendency in highway bridges to erect more substantial and ornamental operator's houses and a considerable number of our highway bridges are equipped with operators' houses of concrete or stone, as illustrated in the preceding pages. This is the tendency now as well in railway bridges, of which the Chicago & Northwestern Railway bridge above referred to is an example. Where it is inconvenient to locate the machinery in the operator's house, it is located in separate waterproof enclosures adjacent or close at hand.

The controllers and switchboard are conveniently located in the house so as to enable the operator to command a view of the switchboard as well as of the river and the roadway or railway. In addition to manual control of the bridge, electrical contacts operated by the movement of the bridge itself, automatically stop the motors in the nearly open and nearly closed positions. In like manner, the lock motor is controlled in its limiting positions. Should the operator neglect to properly control the movement of the bridge and locks, the automatic contacts would thus prevent movement too far in either direction. Moreover, the electric circuits of train signals or highway gates, locks and leaf motors are interlocked to prevent operation of either except in correct sequence. The indicators are either mechanical or electrical, or both, and show the

operator the exact position of the leaf at all times. Similar indicators are provided for the center and end locks. Double leaf bridges can be either controlled by one operator or by two operators. In the former case, a submarine cable connects the electrical equipment between the two leaves and in the latter a bell signal system between operators insures harmonious control. Two operators are desirable only when traffic is highly congested and navigation frequent.

6. GATES AND SIGNALS: In the operation of a movable bridge, protective and signal devices are required, both for the traffic on the bridge and navigation. In highway bridges, the traffic is more difficult to cope with than in railway bridges, since interlocking signals and derails are used, just as in railway crossings.

In Strauss double leaf highway bridges, the leaves when opened themselves form an excellent protective barrier against traffic going off the approaches into the river, and there are no dangerous pits or traps in the approach floor caused by the opening of the leaves. However, the ordinary railway crossing gate is usually installed to serve more as a warning to stop traffic on the bridge, prior to opening, rather than to serve as a positive barrier. These gates, as already referred to under (5), are controlled in the operator's house usually by electricity and have proven satisfactory for the purpose. Visual and audible signals consisting of electric "stop" signs, or "danger" signals, and bells, or gongs, are also installed as extra precautions on busy bridges.

On single leaf bridges and direct lift bridges where traffic is heavy, various types of gates have been used heavy enough to bring oncoming traffic, which ignores signals or has gotten beyond control (particularly automobiles) to an actual stop. Recently, a yielding barrier has been developed and installed, designed to stop automobiles gradually and which, when the automobile is backed away returns to normal position.

Navigation signals consist of either electric or oil lamps, or both, equipped with red lenses, placed permanently on the channel pier or fenders. Fig. 34 (b) illustrates one form of navigation signal, on the bridge itself, consisting of two lenses, one red and one green, curved in the arc of a circle with a lamp suspended from the center arranged to show red, denoting "danger," when the bridge is closed. As the bridge opens the lamp hanging plumb, and the lenses moving through the same angle as the bridge, the color changes to green denoting "clear" at the position of the bridge, when the vessel can proceed through the open draw in safety. In addition to the indicators in the house, referred to under 5, a target (which also shows in this view) aids the operator in properly seating the bridge. A system of whistles or blasts of sirens in the house and on the vessels enables the bridge operator and the navigator to exchange signals for opening the bridge.

7. ROADWAY FLOOR: The floor of the movable section of a bascule bridge assumes especial importance because of its effect upon the

weight. In a railway bridge there is no variation whatever from the tie floors as used on fixed bridges. The standard spacing and size of ties, guards and guard rails, is maintained, and the only additional detail is in the bolting of these parts to the steelwork so that the floor will be held against dislodgement during operation of the bridge.

In highway bridges the floor ordinarily comprises a wearing surface securely spiked to sub-planking, which is in turn spiked to nailing strips bolted to the stringers. Recently, however, more permanent floor construction has been introduced, in the form of wood block paving, treated to prevent deterioration and designed to weigh the minimum possible. These floors also are secured against dislodgement and have proven very satisfactory. At the points where the floor breaks, — i. e., the points between the movable sections and the fixed sections of the bridge, some form of metal guard is generally employed to protect these edges from wear. In all other respects the floor construction is the same as in fixed bridges.

[illegible]
[illegible]

Maintenance

Movable bridge maintenance involves, in addition to ordinary bridge maintenance, only the care of the operating machinery and of the "elements of movement." In Strauss bridges neither of these require more than ordinary skill and effort. The operating machinery, as hereinbefore described, includes only mechanism such as is customary in good machine practice, while our "elements of movement," as already explained, possess the fundamentals of simplicity and efficiency. The only requisite, therefore, for the maintenance of our bridges in good operating condition, is ordinary care and adequate lubrication.

"Electrical current for 12 months		$222.52
Supplies for 12 months:		
55 gals. oil	$5.50	
30 lbs. grease	2.70	
36 250-volt, 16 c. p. lamps	9.00	
40 lbs. waste	2.50	
4 boxes tape	.60	
6 8-inch files	.54	
50 feet bell cord	.26	21.10
Total operating cost for 12 months		$243.62
Repairs (rail casting)		82.11
Total		$325.73
Total number of lifts for 12 months		1,232"

Considering the magnitude of these machines and the service they perform, the maintenance required is so light as to involve no hardship or undue expense upon those who operate these structures. In consequence, our bridges have established uniformly low maintenance records. We quote above extract from the records of the Wheeling & Lake Erie R. R. Co., taken after nine years' service of this Strauss bridge, across the Cuyahoga River, at Cleveland, Ohio.

This being the pioneer Strauss bascule with details not perfected to the same degree as at present, makes this record all the more striking.

Aside from lubrication, trunnions, when properly erected, require no attention throughout the life of the bridge. Nevertheless, our bearings are so designed that both bushings and trunnions may be replaced or adjusted, should occasion arise. For instance, on the Chicago & Northwestern Railroad bridge over the Chicago River near Kinzie Street, which was built in 1908, weighing over 2,000 tons including counterweight, the imperfect alignment of one of the trunnions, present from the date of its erection, was corrected in one hour's time, after 10 years of satisfactory service under an intensity of operating and traffic conditions present in but few movable bridges.

Although Strauss bascules have, in recent years, set new limits of size and weight, nevertheless trunnion efficiency, coupled with sub-division of reactions, counterweight control, and other cardinal features of the Strauss type, still achieve low first costs and low maintenance costs, so that the trunnion and the Strauss bascule together stand for excellence in bascule bridge service, and constitute in themselves a guarantee of dependability and safe and enduring performance.

Strauss Cantilever Swing Bridge

AS supplementary to our bascule and lift types of movable bridges, shown in this Catalogue, we have recently developed a new type of horizontal draw span—our Cantilever Swing Bridge—which reduces the length of the arms, eliminates the continuous girder action and consequent ambiguity, and substitutes for the radial drum, rollers, spiders, rack and center-bearing disc, a series of motor-driven trucks, effecting a gain in both efficiency and economy. This design completes the series of Strauss Operating Bridges, placing us in position, wherever a movable bridge is involved, to serve our clients through the medium of advanced types of all classes.

Partial List of Strauss Bascule and Direct Lift Bridges In Use and Under Construction

GOVERNMENTS

Canada

DEPT. OF PUBLIC WORKS. 160 ft. Single Leaf Bridge over Cataraqui River at Kingston, Ont. Completed: 1917.

59 ft. 8 in. Single Leaf Bridge over the Ship Lock in St. Andrew's Dam at Winnipeg, Man. Completed: 1913.

DEPT. OF RAILWAYS AND CANALS. 165 ft. Single Leaf Bridge over Lachine Canal at Rockfield, Que. Completed: 1914.

108 ft. Single Leaf Bridge over Trent Canal at Campbellford, Ont. Completed: 1914.

73 ft. Single Leaf Bridge over Trent Canal at Wellington Street, Lindsay, Ont. Completed: 1911.

Sweden

GOVERNMENT OF SWEDEN. 61 ft. 8 in. Single Leaf Bridge over Trollhaette Canal. Combined Highway Bridge and Emergency Dam. Completed: 1917.

Santo Domingo

DEPT. OF PUBLIC WORKS, REPUBLIC OF SANTO DOMINGO. 83 ft. Single Leaf Bridge over Ozama River. Total length of structure, 612 ft. Completed: 1917.

United States

U. S. ENGINEER OFFICE, BUFFALO, N. Y. 165 ft. Single Leaf Bridge, 50 ft. wide, over Black Rock Harbor at Ferry Street, Buffalo, N. Y. Completed: 1914.

U. S. ENGINEER OFFICE, LOUISVILLE, KY. 210 ft. Direct Lift Bridge over Louisville and Portland Canal at 18th Street, Louisville, Ky. Completed: 1915.

U. S. ENGINEER OFFICE, NORFOLK, VA. 94 ft. Single Leaf Bridge over Inland Waterway at Coinjock, N. C. Completed: 1916.

94 ft. Single Leaf Bridge over Inland Waterway at Great Bridge, Va. (Duplicate of above). Completed: 1916.

94. ft. Single Leaf Bridge over Inland Waterway at North Landing, Va. (Duplicate of above). Completed: 1916.

U. S. GOVERNMENT. 108 ft. 6 in. Single Leaf Pedestrian Bridge over Mattawoman Creek at the Naval Proving Grounds, Indianhead, Md. Completed: 1917.

U. S. NAVY YARD, DEPARTMENT OF PUBLIC WORKS, MARE ISLAND, CALIFORNIA. 94 ft. Single Leaf Combined Highway and Single Track Railway Bridge in causeway from Mare Island to Vallejo, California.

STATES

CONNECTICUT STATE HIGHWAY COMMISSION. 53 ft. Single Leaf Bridge over Saugatuck River at State Street, City of Westport, Conn. Completed: 1917.

FLORIDA STATE ROAD DEPARTMENT. 124 ft. Double Leaf Bridge over Apalachicola River, Jackson and Gadsen counties, Florida.

ILLINOIS STATE HIGHWAY COMMISSION. 117 ft. 2 in. Single Leaf Bridge over Illinois River at Ottawa, Ill. Completed: 1910.

MARYLAND STATE ROAD COMMISSION. 51 ft. Single Leaf Bridge over College Creek at Annapolis, Md. Completed: 1915.

NEW YORK, STATE OF. 120 ft. Double Leaf Bridge over Tonawanda Creek at Tonawanda, N. Y.

COUNTIES

ATLANTIC COUNTY, N. J. 74 ft. 6 in. Double Leaf Bridge over Beach Thorofare, N. J.

72 ft. 6 in. Double Leaf Bridge over Broad Thorofare on Somers Point—Longport Blvd. Completed: 1916.

BALTIMORE COUNTY, MD. 32 ft. 3 in. Single Leaf Bridge over Back River. Completed: 1912.

BERGEN COUNTY, N. J. 48 ft. Single Leaf Bridge over Hackensack River at River Edge. Completed: 1914.

49 ft. 4 in. Single Leaf Bridge over Overpeck Creek at Leonia, N. J. Completed: 1915.

BERGEN, ESSEX AND HUDSON COUNTIES, N. J. 115 ft. Single Leaf Bridge over Passaic River at Belleville. Total length of structure, 330 ft. Completed: 1915.

BERGEN AND PASSAIC COUNTIES, N. J. 85 ft. Single Leaf Bridge over Passaic River at Eighth Street, Passaic. Total length of structure, 290 ft. Completed: 1915.

BUTLER COUNTY, OHIO. 44 ft. Single Leaf Bridge over Miami & Erie Canal at Poast Town, Ohio. Completed: 1914.

CALCASIEU, PARISH OF, LA. 118 ft. Double Leaf Bridge over Calcasieu River at Lake Charles. Completed: 1916.

CAMDEN COUNTY, N. J. 78 ft. Single Leaf Bridge over Cooper's Creek at Federal Street, Camden. Completed: 1908.

65 ft. Single Leaf Bridge over Newton Creek at Broadway, Camden. Completed: 1915.

CAPE MAY COUNTY, N. J. 72 ft. 6 in. Double Leaf Bridge over Inland Waterway on County Road from Ocean View to Sea Isle City. Completed: 1916.

75 ft. 6 in. Double Leaf Bridge over Main Channel on Corsons Inlet, Ocean City Road, N. J.

DELAWARE COUNTY, PA. 50 ft. Double Leaf Bridge over Darby Creek at Lazarette Road, Media. Total length of structure, 232 ft. 8 in. Completed: 1908.

HAMILTON COUNTY, OHIO. 50 ft. 6 in. Single Leaf Bridge over Miami & Erie Canal at Lockland. Completed: 1908.

JACKSON AND GADSEN COUNTIES, FLA. (See "Highway Bridges—State and Federal Governments.") For Florida State Highway Commission.

LAKE COUNTY, IND. 83 ft. Double Leaf Bridge over East Chicago Canal at 151st Street, East Chicago. Completed: 1916.

MIDDLESEX COUNTY, N. J. 75 ft. Single Leaf Bridge over South River, South Amboy, New Brunswick Road. Completed: 1916.

55 ft. Single Leaf Bridge over Delaware & Raritan Canal at New Brunswick, N. J.

MONMOUTH COUNTY, N. J. 60 ft. Double Leaf Bridge over Mattawan Creek at Keyport. Completed: 1916.

60 ft. Double Leaf Bridge over Shark River between Avon and Belmar, N. J.

MONROE COUNTY, N. Y. 180 ft. Double Leaf Bridge over Genesee River at Stutson Street, Charlotte. Completed: 1918.

MUSKINGUM COUNTY, OHIO. 75 ft. Single Leaf Bridge over Muskingum River at 6th Street, Zanesville. Completed: 1915.

NEW CASTLE COUNTY, DEL. 172 ft. Double Leaf Bridge over Christiana River at Third Street, Wilmington, Completed: 1916.

NUECES COUNTY, TEXAS. 42 ft. Single Leaf Bridge for Corpus Christi Causeway. Completed: 1915.

SACRAMENTO COUNTY, CAL. 226 ft. Double Leaf Bridge over Sacramento River at Walnut Grove. Total length of structure, 380 ft. Completed: 1916.

SACRAMENTO AND SOLANO COUNTIES, CAL. 226 ft. Double Leaf Bridge over Sacramento River at Rio Vista, Cal.

SACRAMENTO COUNTY HIGHWAY COMMISSION. 226 ft. Double Leaf Bridge over Sacramento River at Isleton, Cal.

SNOHOMISH COUNTY, WASH. 112 ft. Single Leaf Bridge over Ebey Slough at Lot 4, Sec. 3, Twp. 28, N. R. 5 E. Completed: 1913.

STARK COUNTY, OHIO. 31 ft. 6 in. Single Leaf Bridge. 100 ft. wide, over Ohio & Erie Canal at Massillon. Completed: 1914. *The widest Bascule in the world.*

UNION COUNTY, N. J. 85 ft. Single Leaf Bridge over Elizabeth River at Baltic Street, Elizabeth. Completed: 1916.

78 ft. Single Leaf Bridge over Elizabeth River at First Street, Elizabeth. Completed: 1910.

58 ft. 6 in. Single Leaf Bridge over Elizabeth River at South Street, Elizabeth.

155 ft. Single Leaf Bridge over Elizabeth River at South Front Street, Elizabeth.

WAYNE COUNTY, MICH. 112 ft. Single Leaf Bridge over River Rouge, at Dix Road. Completed: 1913.

WICOMICO COUNTY, MD. 58 ft. Single Leaf Bridge over Wicomico River at Camden Avenue, Salisbury. Completed: 1915.

51 ft. 10 in. Single Leaf Bridge over Wicomico River at South Division Street, Salisbury. Completed: 1915.

CITIES

Canada

IBERVILLE, TOWN OF, QUE. 44 ft. 3 in. Single Leaf Bridge over Richelieu River. Completed: 1916.

OTTAWA, CITY OF, ONT. 88 ft. *Direct Lift Bridge* over Rideau Canal near Pretoria Ave. Total length of structure, 200 ft. Completed: 1918.

QUEBEC, CITY OF, QUE. 149 ft. Single Leaf Bridge over St. Charles River (Dorchester Bridge). Completed: 1915.

149 ft. Single Leaf Bridge over St. Charles River (Druin Bridge). Completed: 1914.

85 ft. 6 in. Single Leaf Bridge over St. Charles River. (Bickell's Bridge.) Completed: 1916.

ST. JOHNS, TOWN OF, QUE. 84 ft. 9 in. Single Leaf Bridge over Chambly Canal. Completed: 1916.

TORONTO, CITY OF, ONT. 129 ft. Single Leaf Bridge over Keatings Channel at Cherry Street. (Built jointly by City and Toronto Harbor Commission.) Completed: 1918.

WINNIPEG, CITY OF, MAN. 112 ft. 6 in. Double Leaf Bridge over Assiniboine River at Osborne Street. Completed: 1914.

Cuba

HAVANA, CITY OF. (See "Highway Bridges—Municipal and other Corporations"). For Jose Lopez Rodriguez and Raymon D. Mendoza.

Denmark

COPENHAGEN, CITY AND HARBOR BOARD OF DENMARK. Knippels Bridge, 109 ft. 2 in. Double Leaf Bridge. Completed: 1909.

Russia

PETROGRAD, CITY OF, RUSSIA. Palace Bridge, 209 ft. Double Leaf Bridge, 90 ft. wide over Neva River. The most elaborate bascule bridge in the world, leading directly to the former Czar's famous Winter Palace. Completed: 1916.

Sweden

CITY OF STOCKHOLM, SWEDEN. Klaraviken Bridge. 61 ft. Double Leaf Bridge, 63 ft. wide.

United States

ANNAPOLIS, CITY OF, MD. (See "Highway Bridges—State Governments"). For Maryland State Road Commission.

BOSTON, CITY OF, MASS. 103 ft. Single Leaf Bridge over Mystic River at Alford Street. (Built by Boston Elevated Ry. for highway use. Completed: 1917.

BRIDGEPORT, CITY OF, CONN. 155 ft. Double Leaf Bridge over Pequonnock River at Stratford Avenue.

96 ft. Single Leaf Bridge over Pequonnock River at Grand Street. Total length of structure, including approaches, 1,150 ft.

91 ft. Single Leaf Bridge over Pequonnock River at Washington Avenue. Total length of structure, 225 ft.

CITY OF BUFFALO, N. Y. 132 ft. 3 in. Single Leaf Bridge over Buffalo River at Abbott Road. Total length of structure, including approaches, 288 ft. 6 in.

CHICAGO, CITY OF, ILL. 193 ft. Double Leaf Bridge over South Branch of Chicago River at Polk Street. Completed: 1910.

240 ft. *Direct Lift Bridge* over South Branch of Chicago River at Twelfth Street. Total length of structure, 320 ft. (Plans prepared.)

202 ft. Double Leaf Bridge over South Branch Chicago River at Jackson Street. (Bridge built by Sanitary District, operated by City.) *One of the most important Bascule Bridges in Chicago; leading to the new Union Depot, under construction.* Completed: 1916.

FALMOUTH, TOWN OF, MASS. 40 ft. Single Leaf Bridge over Eel Pond Channel at Woods Hole. Completed: 1914.

GREEN BAY, CITY OF, WIS. 74 ft. Single Leaf Bridge over East River at Main Street. Completed: 1916.

118 ft. Single Leaf Bridge over Fox River at Mason Street. Total length of structure, 726 ft. Completed: 1915.

99 ft. 9 in. Single Leaf Bridge over Fox River at Walnut Street. Total length of structure, 901 feet. Completed: 1910.

NEW HAVEN, CITY OF, CONN. 148 ft. Double Leaf Bridge over Quinnipiack River at Forbes Ave.

NEW ORLEANS, CITY OF, LA. 40 ft. Single Leaf Bridge over Channel connecting New Basin Canal with Southern Yacht Club Pen. Completed: 1915.

65 ft. Single Leaf Bridge over New Basin Canal at City Park Ave. Completed: 1915.

65 ft. Single Leaf Bridge over New Basin Canal at Lake Street. Completed: 1914.

65 ft. 3 in. Single Leaf Bridge over Old Basin Canal at Hagan Ave. Completed: 1913.

64 ft. 8 in. Single Leaf Bridge over New Basin Canal at West End Park. Total length of structure 194 ft. (Foot Bridge built by New Orleans Ry. & Lt. Co.; used by City.) Completed: 1916.

OTTAWA, CITY OF, ILL. (See "Highway Bridges—State Governments.") For Illinois State Highway Commission.

PETALUMA, CITY OF, CAL. 60 ft. Double Leaf Bridge over Petaluma Creek at Washington Street. Completed: 1914.

PORT HURON, CITY OF, MICH. 82 ft. 6 in. Double Leaf Bridge, 65 ft. wide, over Black River at Military Street. Completed: 1914.

SAN FRANCISCO, CITY OF, CAL. 94 ft. Single Leaf Bridge over Channel Street Waterway at Fourth Street. Completed: 1917.

TRENTON, CITY OF, N. J. 33 ft. 6 in. Single Leaf Bridge over Delaware & Raritan Canal at Broad Street. (Bridge built by Pennsylvania R. R. for Highway use.)

WESTPORT, CITY OF, CONN. (See "Highway Bridges—State Governments.") For Connecticut State Highway Commission.

MUNICIPAL AND OTHER CORPORATIONS

GRANITE AVENUE BRIDGE COMMISSION. (Representing City of Quincy, Town of Milton, and Counties of Norfolk and Suffolk, Mass.) 70 ft. Single Leaf Bridge over Neponset River at Granite Ave. Completed: 1914.

ISLAND HEIGHTS & SEASIDE PARK BRIDGE CO. 59 ft. Single Leaf Bridge over Barnegat Bay at Island Heights, N. J. Completed: 1914.

NORFOLK-BERKLEY BRIDGE CORPORATION. 168 ft. Double Leaf Bridge over East Branch of the Elizabeth River, Norfolk, Va. Completed: 1918.

PORT ARTHUR PLEASURE PIER CO. 104 ft. 6 in. Single Leaf Bridge over Sabine Neches Canal at Port Arthur, Tex. Completed. 1914.

JOSE LOPEZ RODRIGUEZ AND RAYMON D. MENDOZA. 111 ft. Double Leaf Bridge over Almendares River at Havana, Cuba. Total length of structure, 419 ft.

SANITARY DISTRICT OF CHICAGO. (See "Highway Bridges," City of Chicago.)

TORONTO HARBOR COMMISSION. (See "Highway Bridges," City of Toronto.)

COMBINED HIGHWAY AND RAILWAY BRIDGES

Canada

CANADIAN PACIFIC RY. 186 ft. Single Leaf, Double Deck Bridge over Kaministiquia River at Ft. William, Ont. Double Track railway on lower deck and 29 ft. roadway on upper deck. Completed: 1914. *The first Double Deck Bascule in the world.*

GRAND TRUNK PACIFIC R. R. 105 ft. 6 in. *Direct Lift Bridge* over Fraser River at Fort George, B. C. Single Track R. R. and two 12 ft. roadways. Completed: 1914

Egypt

EGYPTIAN STATE RYS. Hamoul Bridge. 50 ft. 10¼ in. Single Leaf Bridge. Single track railway and two 6 ft. 6 in. roadways. Two identical bridges.

Sweden

CITY OF STOCKHOLM, SWEDEN. 131 ft. 6 in. Single Leaf, combined Highway and Railway Bridge over Inloppskanalen Canal at Danviken.

United States

ATCHISON, TOPEKA & SANTA FE SYSTEM AND SOUTHERN PACIFIC CO. 105 ft. Single Leaf Bridge over Islais Creek at Kentucky Street, San Francisco, Cal. Double track railway, two 10 ft. wagon roads, and two 6 ft. sidewalks. Completed: 1915.

BOARD OF PORT COMMISSIONERS, NEW ORLEANS, LA. 93 ft. 6 in. Single Leaf, Double Track Bridge, two 11 ft. roadways and two 4 ft. sidewalks, over Industrial Canal at St. Claude Ave., New Orleans.

Three 117 ft. Single Leaf, Double Track Bridges, two 11 ft. roadways and two 4 ft. sidewalks, over Industrial Canal at the following crossings: Florida Walk; Louisville & Nashville R. R.; Southern R. R.

RAILWAY BRIDGES

Canada

CANADIAN NORTHERN RY. 93 ft. Single Leaf, Double Track Bridge over Assiniboine River at Winnipeg, Man. Completed: 1912.

(Freight tracks) 101 ft. Single Leaf, Double Track Bridge over Assiniboine River at Winnipeg, Man. Completed: 1914.

96 ft. Single Leaf, Double Track Bridge over Rainy Lake, Ont. Completed: 1914.

CANADIAN PACIFIC RY. 336 ft. Double Leaf, Single Track Bridge over New U. S. Ship Canal at Sault Ste. Marie. Completed: 1914. *The longest Double Leaf Bascule Bridge in the world.*

108 ft. 1 in. Single Leaf, Double Track Bridge over South Saskatchewan River near Medicine Hat, Alberta. Completed: 1913.

DEPT. OF RAILWAYS AND CANALS. 83 ft. Single Leaf, Single Track Bridge over Trent Canal for Grand Trunk Ry. Completed: 1913.

GRAND TRUNK PACIFIC RY. 55 ft. Single Leaf Single Track Bridge over Ky-Ax River. Completed: 1914.

HARBOR COMMISSIONERS OF QUEBEC. Cross Wall Bridge over Entrance to Princess Louise Docks at Quebec. 88 ft. Single Leaf, Single Track Bridge. Completed: 1912.

NATIONAL TRANSCONTINENTAL RY. 129 ft. 6 in. Single Leaf, Double Track Bridge over Red River at Winnipeg, Man. Completed: 1912.

NIAGARA, ST. CATHERINES & TORONTO RY. 55 ft. 6 in. Single Leaf, Single Track Bridge over Welland Canal Feeder. Completed: 1911.

Norway

NORWEGIAN STATE RYS. 131 ft. 2½ in. Single Leaf, Double Track Bridge at Trondhjem, Norway. Completed: 1917.

Panama Canal Zone

ISTHMIAN CANAL COMMISSION. 104 ft. 8¾ in. Single Leaf, Single Track Bridge over Gatun River at Colon, Panama Canal Zone, for Panama Railroad. Completed: 1913.

Sweden

STATE RAILWAYS OF SWEDEN. 137 ft. 9½ in. Single Leaf, Single Track Bridge over Trollhaette Canal. Completed: 1916.

Mexico

TAMPICO-PANUCO VALLEY RY., MEXICO. 97 ft. 6 in. Single Leaf, Single Track Bridge on Estero Topila Section. Total length of structure, 196 ft. 6 in.

United States

ATCHISON, TOPEKA & SANTA FE SYSTEM (Houston Belt & Terminal Ry Co.) 111 ft. 6 in. Single Leaf Single Track Bridge over Buffalo Bayou at Houston, Tex. Completed: 1913.

ATLANTIC COAST LINE R. R. 117 ft. 6 in. Single Leaf, Single Track Bridge over Altamaha River near Doctortown, Ga. Completed: 1914.

ATLANTIC COAST LINE RY. AND SEABOARD AIR LINE RY. 111 ft. 6 in. Single Leaf, Single Track Bridge over N. E. Cape Fear River at Hilton, N. C. Completed: 1916.

BALTIMORE & OHIO R. R. (S. I. R. T. R. R.) 50 ft. 3 in. Single Leaf, Double Track Bridge over Bodine Creek at Richmond, Staten Island, N. Y. Completed: 1907.

235 ft. Single Leaf, Double Track Bridge over Calumet River at South Chicago, Ill. Completed: 1914.

235 ft. Single Leaf, Double Track Bridge over Calumet River at South Chicago, Ill. (Duplicate).

(Baltimore & Ohio Chicago Terminal R. R., Whiting Branch). 90 ft. Single Leaf, Double Track Bridge over East Chicago Canal. Completed: 1914.

74 ft. Single Leaf, Double Track Bridge at Zanesville, Ohio. Completed: 1912.

BOSTON AND ALBANY R. R. CO. 104 ft. Single Leaf, Double Track Bridge over Chelsea Creek between Chelsea and East Boston, Mass.

BOSTON & MAINE R. R. 65 ft. Single Leaf, Double Track Bridge at Manchester, Mass. Completed: 1911.

65 ft. Single Leaf, Double Track Bridge over Saugus River. Manchester, Mass. Completed: 1912.

65 ft. Single Leaf, Double Track Bridge over Saugus River, near West Lynn, Mass. (Duplicate). Completed: 1912.

52 ft. 4 in. Single Leaf, Double Track Bridge over Squam River near Gloucester, Mass. Completed: 1911.

BOSTON ELEVATED RY. 70 ft. Single Leaf, Double Track Bridge over Charles River. Completed: 1912.

95 ft. Single Leaf Bridge over Mystic River. Malden & Everett Extension. Completed: 1917.

Alford St. Bridge. (See "Highway Bridges," City of Boston.)

BUFFALO CREEK R. R. 174 ft. Single Leaf, Double Track Bridge over Buffalo River at Buffalo, N. Y. Completed: 1914.

CAPE COD CONSTRUCTION CO. 159 ft. 4 in. Single Leaf, Double Track Bridge over Cape Cod Canal at Buzzard's Bay, Mass., for N. Y., N. H. & H. R. R. Completed: 1910.

C., C., C. & ST. L. R. R. CO. 175 ft. Single Leaf, Single Track Bridge over Cuyahoga River at Cleveland, Ohio.

CHICAGO & NORTHWESTERN RY. 180 ft. Single Leaf, Three Track Bridge over North Branch Chicago River at Deering (Chicago). Completed: 1916.

170 ft. Single Leaf, Double Track Bridge over North Branch Chicago River at Kinzie Street, Chicago, Ill. Completed: 1908.

CHICAGO & WESTERN INDIANA R. R. 186 ft. Single Leaf, Double Track Bridge over Calumet River at South Chicago, Ill. Completed: 1912.

DELAWARE, LACKAWANNA & WESTERN R. R. 125 ft. Single Leaf, Double Track Bridge over Buffalo River at Buffalo, N. Y. Completed: 1915.

ERIE R. R. 180 ft. Single Leaf, Double Track Bridge over Cuyahoga River at Cleveland, Ohio. Completed: 1911.

(New York Div.). 151 ft. Single Leaf, Double Track Bridge over Hackensack River. Completed: 1911.

(New York Div.). 151 ft. Single Leaf, Double Track Bridge over Hackensack River. (Duplicate).

(N. Y. S. & W. R. R.) 55 ft. 5 in. Single Leaf, Double Track Bridge over Overpeck Creek at Little Ferry, N. J. Completed: 1911.

FLORIDA EAST COAST RY. 63 ft. 6 in. Single Leaf, Single Track Bridge over New River at Ft. Lauderdale, Fla. Completed: 1910.

63 ft. 6 in. Single Leaf, Single Track Bridge over Pablo Creek. (Duplicate of New River Bridge at Ft. Lauderdale, Fla.) Completed: 1911.

63 ft. 6 in. Single Leaf, Single Track Bridge over St. Johns River, Volusia County, Fla. (Second duplicate of New River Bridge at Ft. Lauderdale, Fla.) Completed: 1912.

GREAT NORTHERN RY. 206 ft. 7 in. Single Leaf, Double Track Bridge over Salmon Bay Waterway at Seattle, Wash. Completed: 1914.

ILLINOIS CENTRAL R. R. 99 ft. 3 in. Single Leaf, Single Track Bridge over Galena River at Galena, Ill. Completed: 1914.

99 ft. 3 in. Single Leaf, Single Track Bridge over New Basin Canal, New Orleans, La. (Duplicate of bridge over Galena River). Completed: 1916.

77 ft. Single Leaf Bridge over Big Black River at Allen, Miss. Completed: 1917.

260 ft. Single Leaf, Double Track Bridge over South Branch of the Chicago River at Chicago, Ill. (*The longest single leaf bascule bridge in the world.*)

INTERNATIONAL & GREAT NORTHERN RY. 110 ft. 6 in. Single Leaf, Single Track Bridge over Buffalo Bayou at Houston, Tex. Completed: 1915.

MICHIGAN CENTRAL R. R. CO. 145 ft. Single Leaf, Double Track Bridge over Rouge River near Detroit, Michigan.

MISSOURI PACIFIC RY. (St. L. I. M. & S. R. R.) 38 ft. 10 in. Single Leaf, Single Track Bridge over Black River. Completed: 1907.

NEW ORLEANS RY. & LIGHT CO. (See "Highway Bridges," City of New Orleans.)

NEW YORK CENTRAL LINES. 159 ft. 4 in. Single Leaf, Double Track Bridge. (Duplicate of N. Y., N. H. & H. R. R. Bridge over Cape Cod Canal at Buzzard's Bay, Mass.) at Ashtabula Harbor, Ohio. Completed: 1911.

132 ft. 7⅝ in. Single Leaf, Double Track Bridge over Buffalo Creek at Buffalo, N. Y. Completed: 1913

125 ft. Single Leaf, Double Track Bridge over Tonawanda Creek at Tonawanda, N. Y.

118 ft. Single Leaf, Four Track Bridge over Portage River at Port Clinton, Ohio. Completed: 1915. *This and following structures constitute the only Four Track Bascules in the world.*

NEW YORK CONNECTING RY. Two 175 ft. Four Track, Single Leaf Bridges over Bronx Kills, N. Y. Completed: 1915.

NEW YORK, NEW HAVEN & HARTFORD R. R. 40 ft. Single Leaf, Double Track Bridge over Cohasset Narrows, near Buzzard's Bay, Mass. Completed: 1912.

39 ft. 9 in. Single Leaf, Single Track Bridge over North River at Marshfield, Mass. Completed: 1911.

188 ft. Single Leaf, Double Track Bridge over Thames River at New London, Conn.

NORTHERN PACIFIC RY. 160 ft. Single Leaf, Single Track Bridge over Duwamish River at Seattle, Wash. Completed: 1911.

191 ft. Single Leaf, Single Track Bridge over Lake Washington Canal at Seattle, Wash. Completed: 1914.

96 ft. Double Track, *Direct Lift Bridge* over Steilacoom Creek at Tacoma, Wash. Completed: 1914.

OHIO ELECTRIC RY. 73 ft. 6 in. Single Leaf, Single Track Bridge over Swan Creek at Toledo, Ohio. Completed: 1909.

PENNSYLVANIA R. R. (See "Highway Bridges," City of Trenton, N. J.)

63 ft. Single Leaf, Double Track Bridge over Crum River near Eddystone, Pa. Completed: 1918.

63 ft. Single Leaf, Double Track Bridge over Darby River near Eddystone, Pa. Completed: 1918.

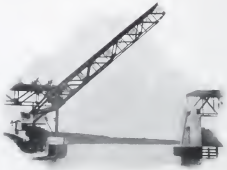
PEORIA & PEKIN UNION RY. 159 ft. 4 in. Single Leaf, Double Track Bridge over Illinois River at Peoria, Ill. Completed: 1911.

PUBLIC SERVICE RY. CO. OF NEW JERSEY. 83 ft. Single Leaf, Double Track Bridge over Rahway River at East Rahway, N. J. Completed: 1907.

SAN ANTONIO & ARANSAS PASS RY. 39 ft. 9 in. Single Leaf, Single Track Bridge over Corpus Christi Reef. Completed: 1913.

SOUTHERN PACIFIC CO. (Los Angeles Div.) 187 ft. 6 in. Single Leaf, Double Track Bridge near San Pedro, Cal. Completed: 1912.

WABASH R. R. (W. & L. E. R. R.) 150 ft. Single Leaf, Single Track Bridge over Cuyahoga River at Cleveland, Ohio. Completed: 1905.



Ozama River Bridge, Santo Domingo

Strauss Service

From the preceding list it will be observed that Strauss service is not limited to the United States and Canada, Strauss bridges being found in Cuba, Santo Domingo, Mexico, Panama, Norway, Sweden, Denmark, Egypt and Russia. It will also be noted that among the prominent Railway Companies which Strauss bridges serve are the following:

Atchison, Topeka & Santa Fe Ry. Co.
Atlantic Coast Line Ry. Co.
Baltimore & Ohio R. R. Co.
Boston Elevated Ry. Co.
Boston & Albany R. R. Co.
Boston & Maine R. R. Co.
Chicago & Northwestern Ry. Co.
Canadian Pacific Ry. Co.
Canadian National Ry. Co.
Delaware, Lackawanna & Western R. R. Co.
Egyptian State Rys.
Erie Railroad Company.
Great Northern Ry. Co.
Grand Trunk Pacific Ry. Co.
Illinois Central R. R. Co.
Florida, East Coast Ry. Co.

Norwegian State Rys.
New York Central Lines, comprising the following companies:
- New York Central R. R. Co.
- Lake Shore & Michigan Southern Ry. Co.
- Michigan Central R. R. Co.
- Boston & Albany R. R. Co.
- C., C., C. & St. L. (Big Four) Ry. Co.

Northern Pacific Ry. Co.
New York, New Haven & Hartford R. R. Co.
Pacific Electric Ry. Co.
Pennsylvania Railroad Co.
Seaboard Air Line Ry. Co.
Southern Pacific Ry. Co.
State Rys. of Sweden.
Tampico-Panuco Valley Ry. Co., Mexico.

Strauss Service includes representation in various parts of the world, thus providing for consultation and advice in our behalf with those contemplating movable bridge work abroad. In this country our main office is centrally located at Chicago with branch offices at New York and Montreal. We are, therefore, in position to give prompt attention to clients everywhere.

We prepare preliminary sketches and estimates where necessary as a guide to those making appropriations or in order to assist our clients in determining the proper type of bridge for each location We make a specialty of solving difficult problems and invite the presentation to us of all matters relating to movable bridges.

THE money value of Strauss Bridges in service exceeds $25,000,000.00. Their value in terms of the world's commerce is measured by the millions of tons that, year after year, steam through their opened leaves and pass in endless stream across their roadways.

DESIGNED AND EXECUTED BY
THE MERCANTILE PRINTING COMPANY
CHICAGO